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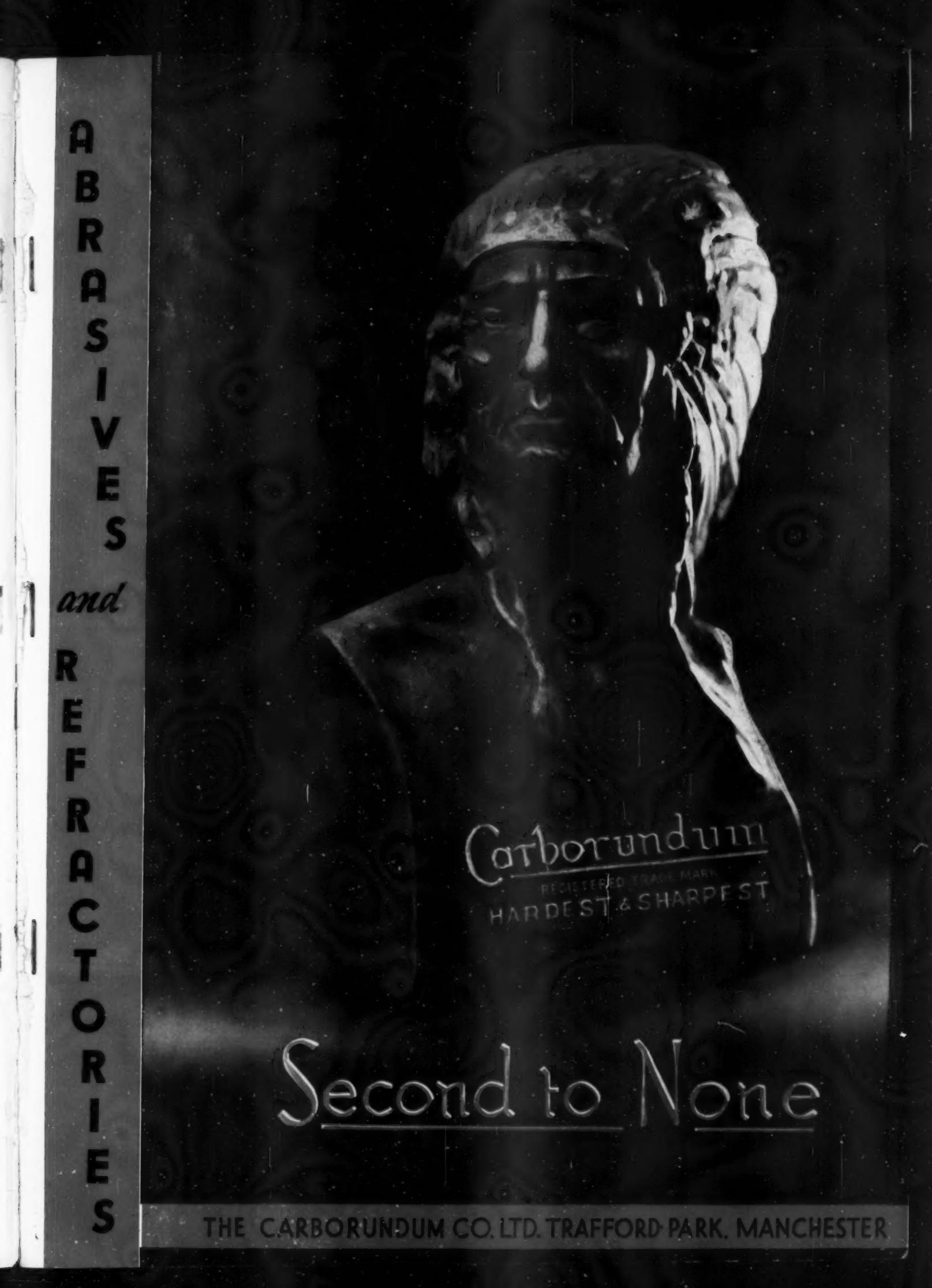
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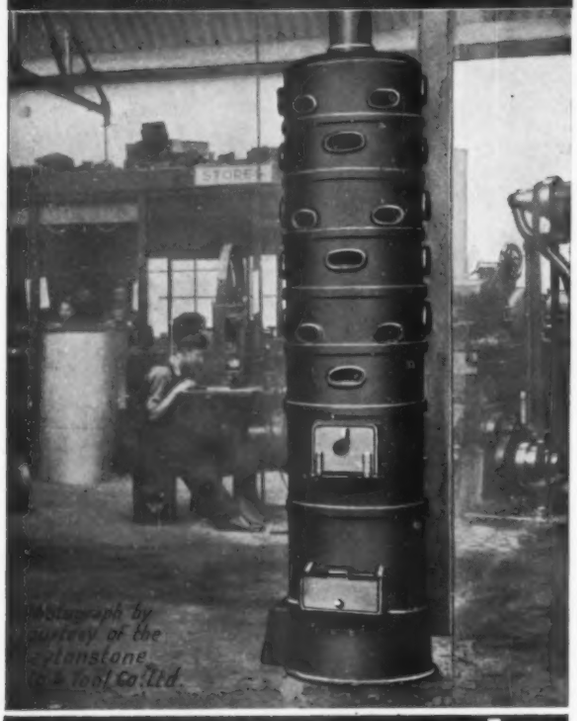

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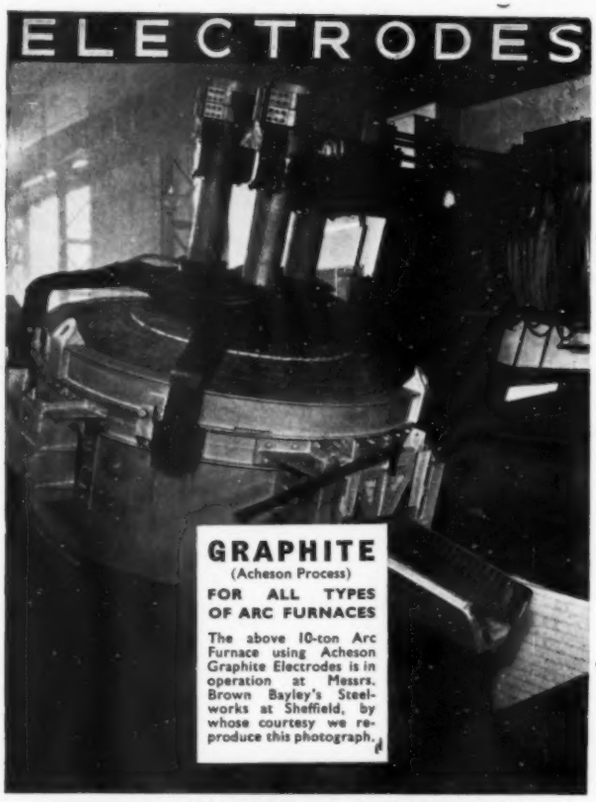

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The above 10-ton Arc Furnace using Acheson Graphite Electrodes is in operation at Messrs. Brown Bayley's Steelworks at Sheffield, by whose courtesy we reproduce this photograph.

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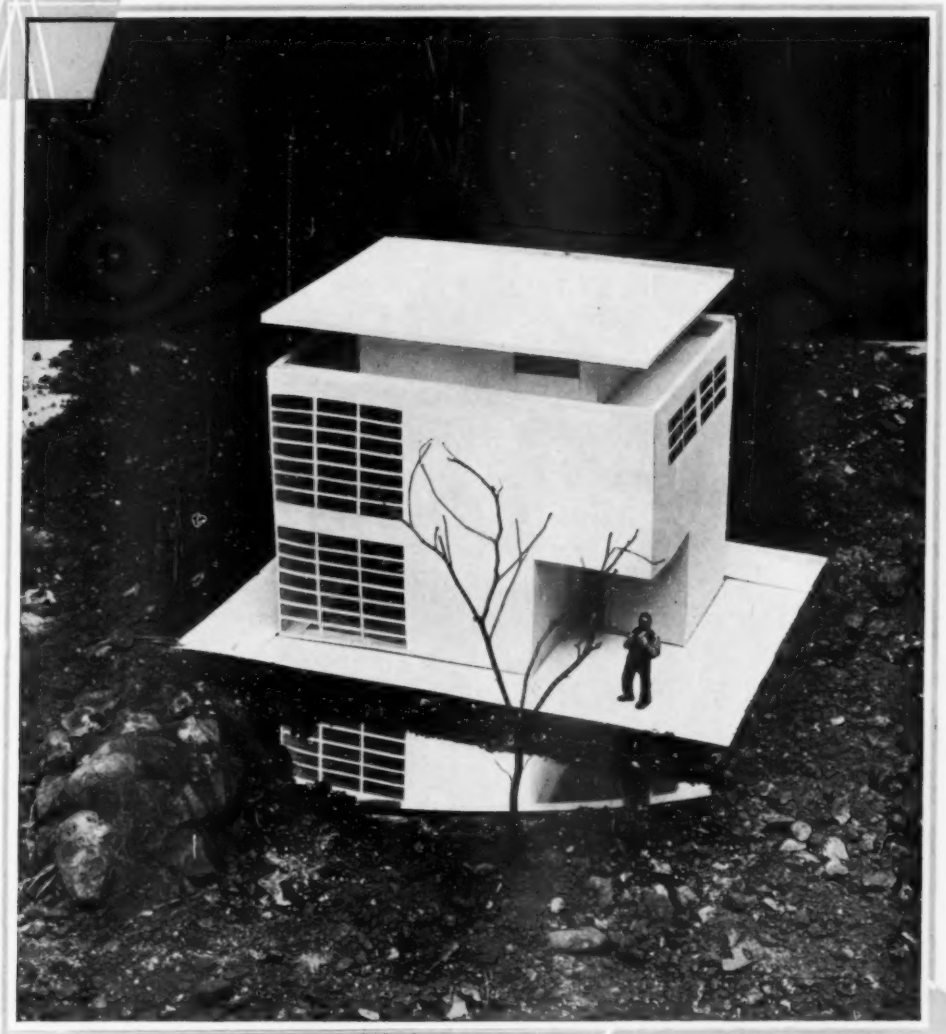

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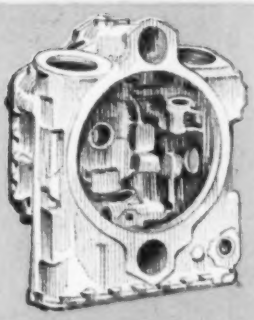

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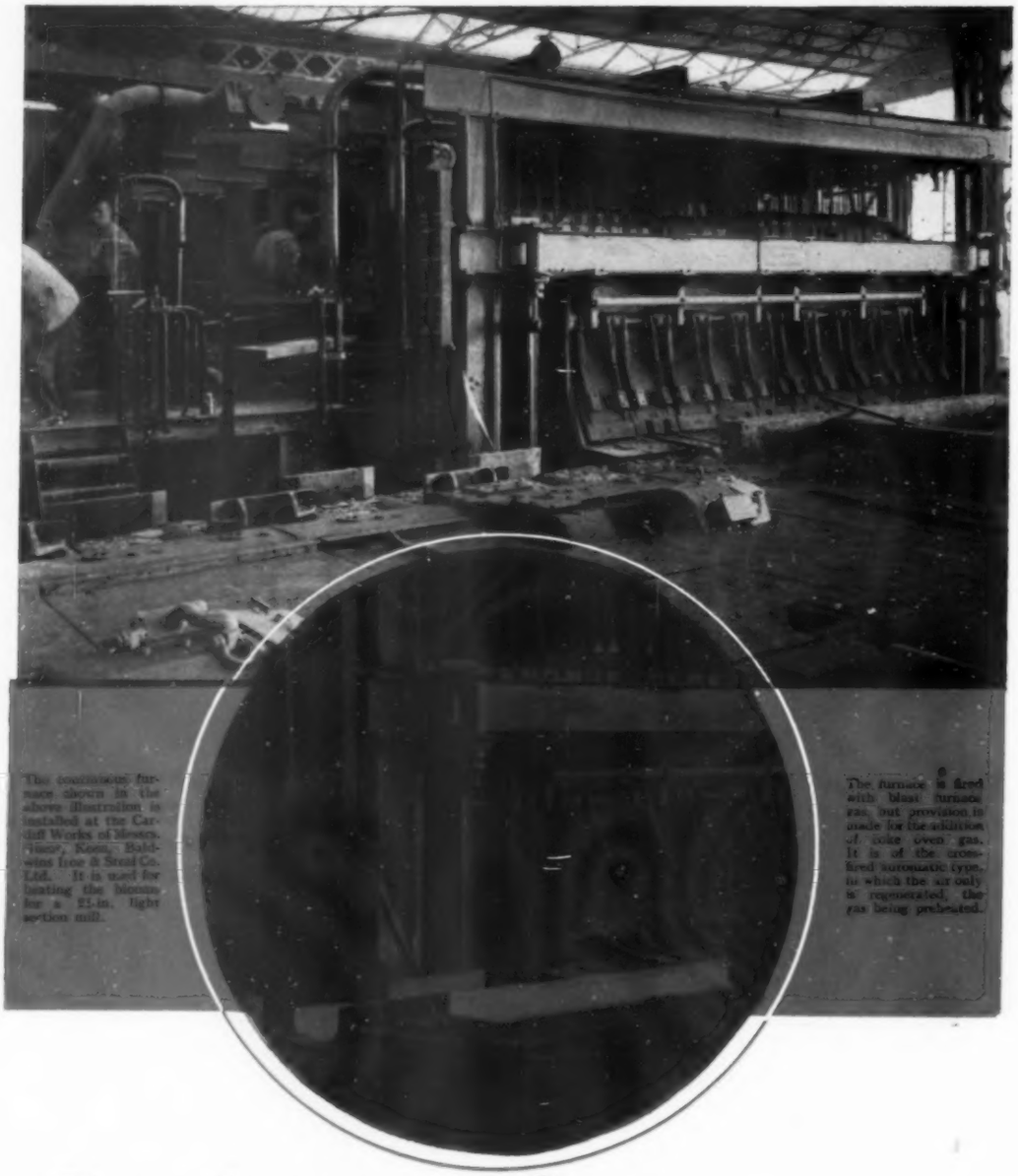

The continuous furnace shown in the above illustration is installed at the Cardiff Works of Messrs. Guest, Keen, Baldwins Iron & Steel Co. Ltd. It is used for heating the blooms for a 12-in. light section mill.

The furnace is fired with blast furnace gas, but provision is made for the addition of coke oven gas. It is of the cross-fired automatic type, in which the air only is regenerated, the gas being preheated.

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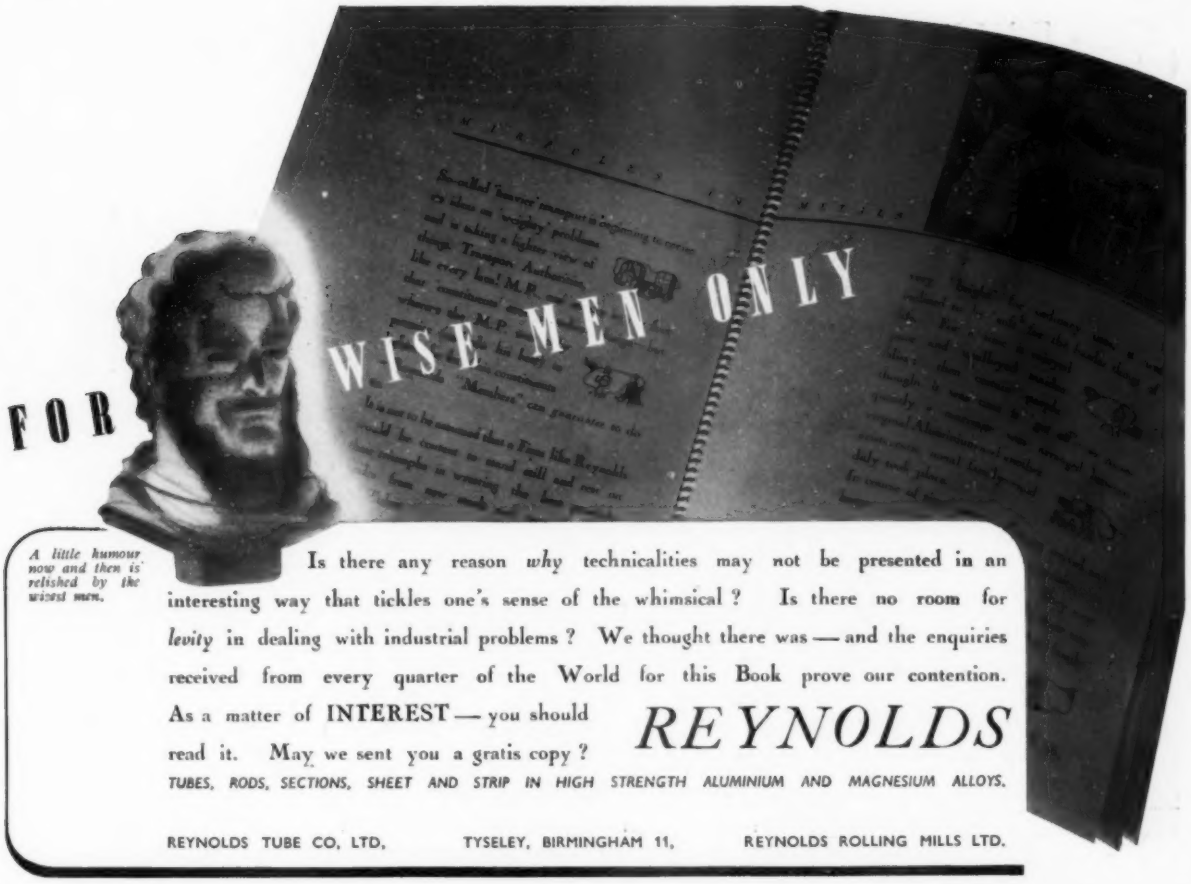

A little humour now and then is relished by the wisest men.

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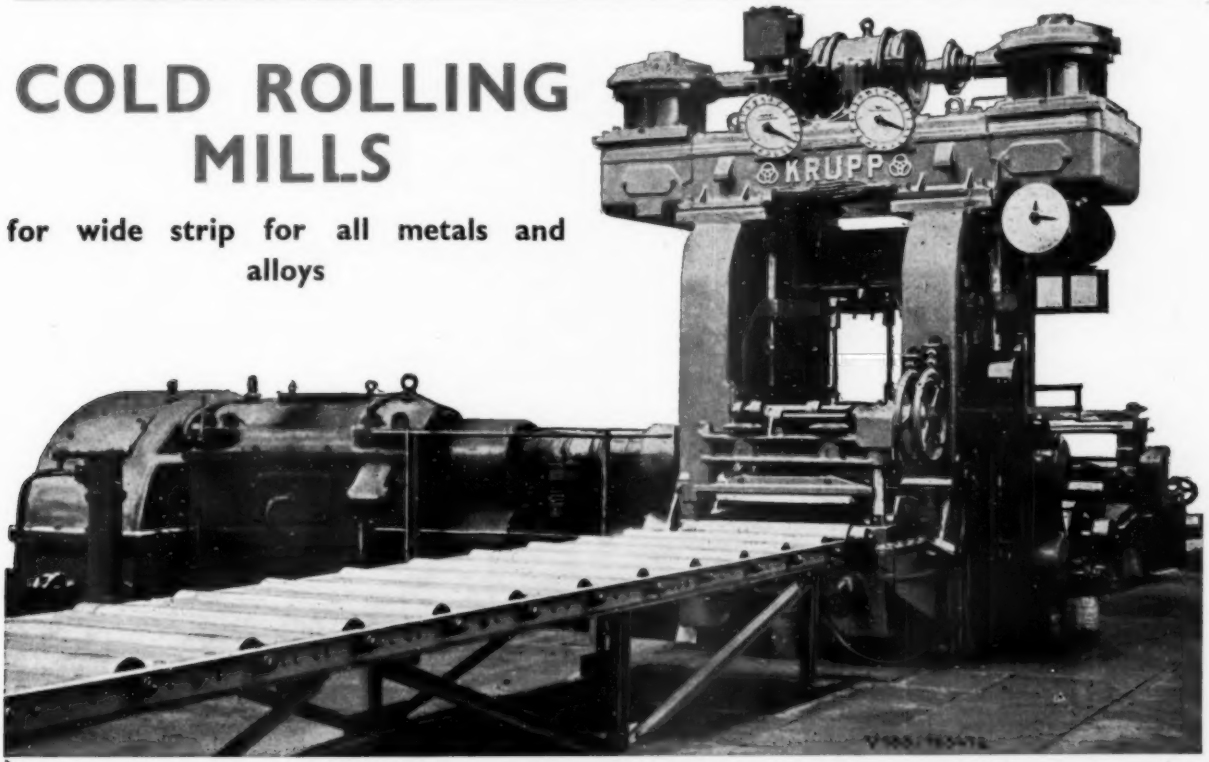

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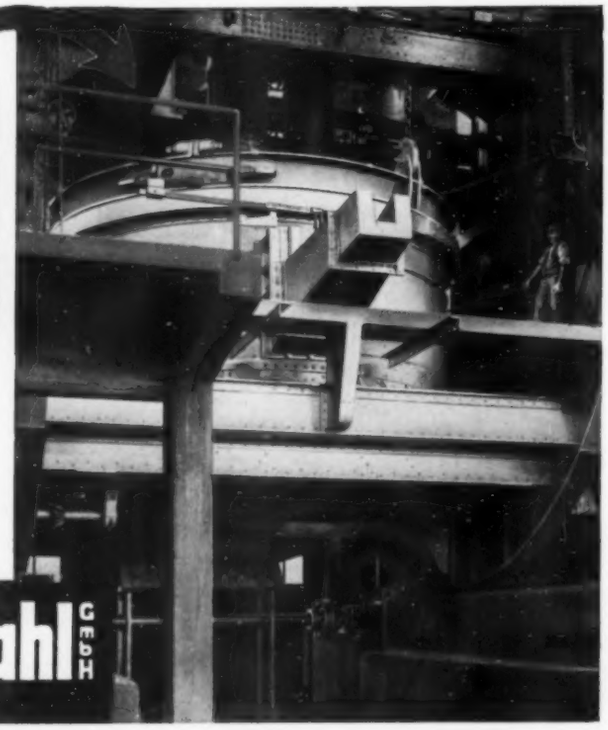

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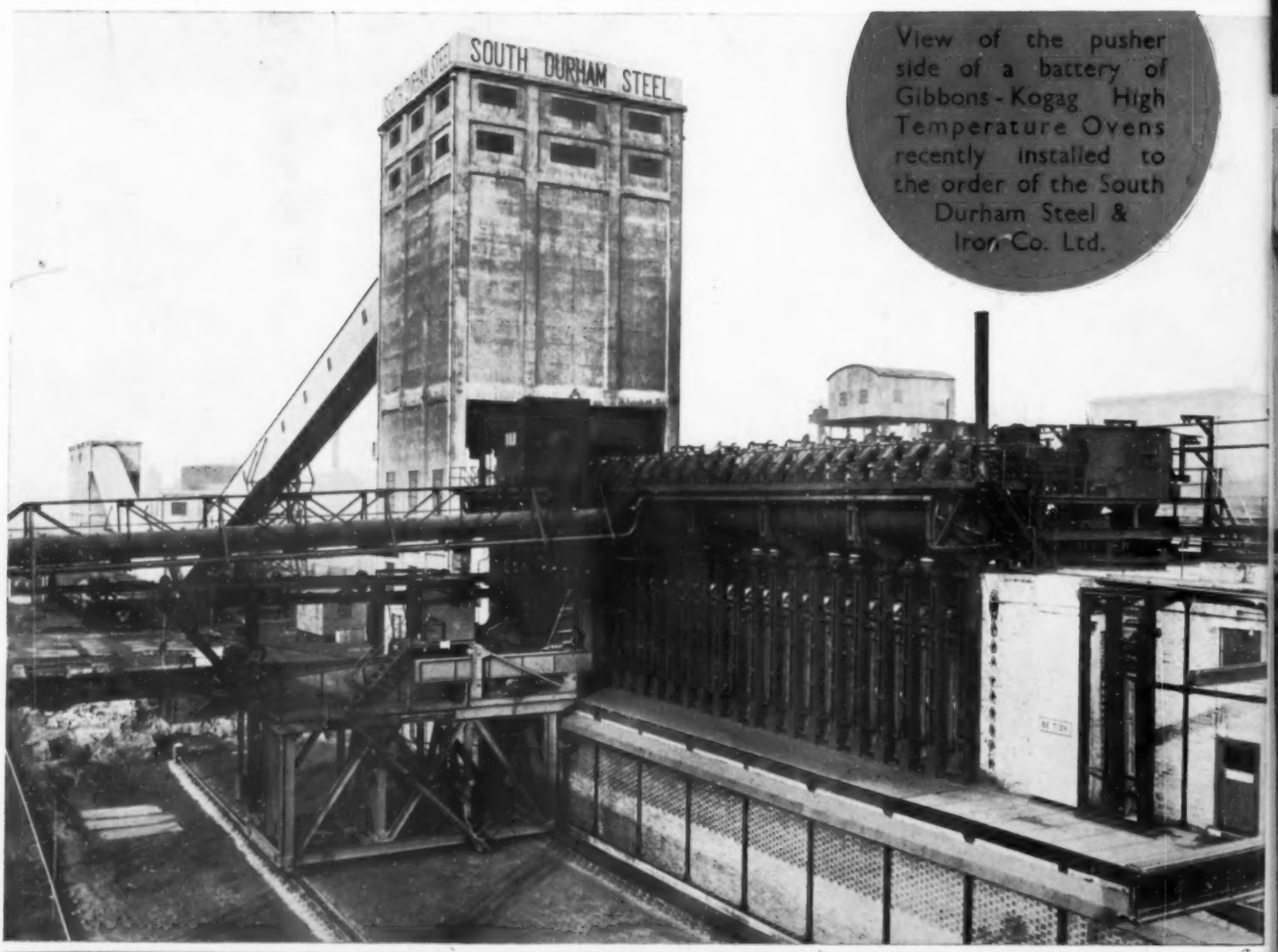

View of the pusher side of a battery of Gibbons-Kogag High Temperature Ovens recently installed to the order of the South Durham Steel & Iron Co. Ltd.

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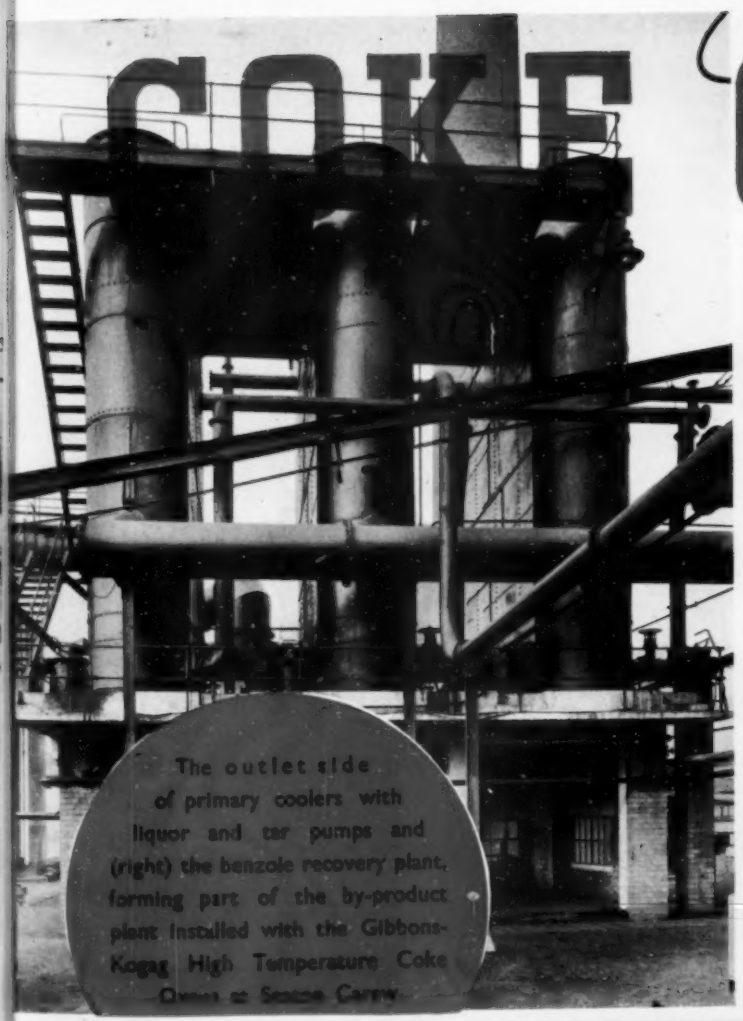

The outlet side of primary coolers with liquor and tar pumps and (right) the benzole recovery plant, forming part of the by-product plant installed with the Gibbons-Kogag High Temperature Coke Ovens at Seaton Carew

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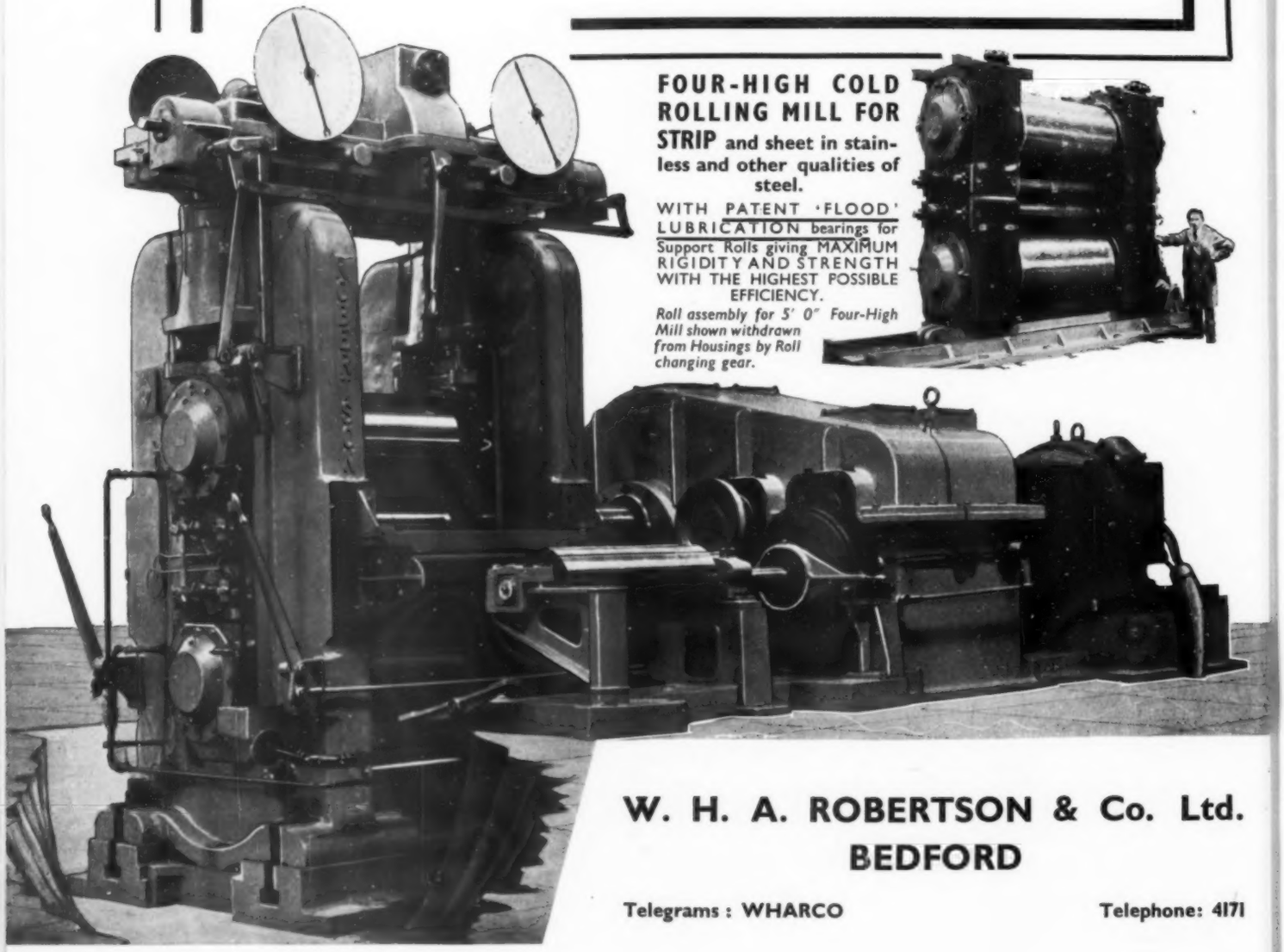

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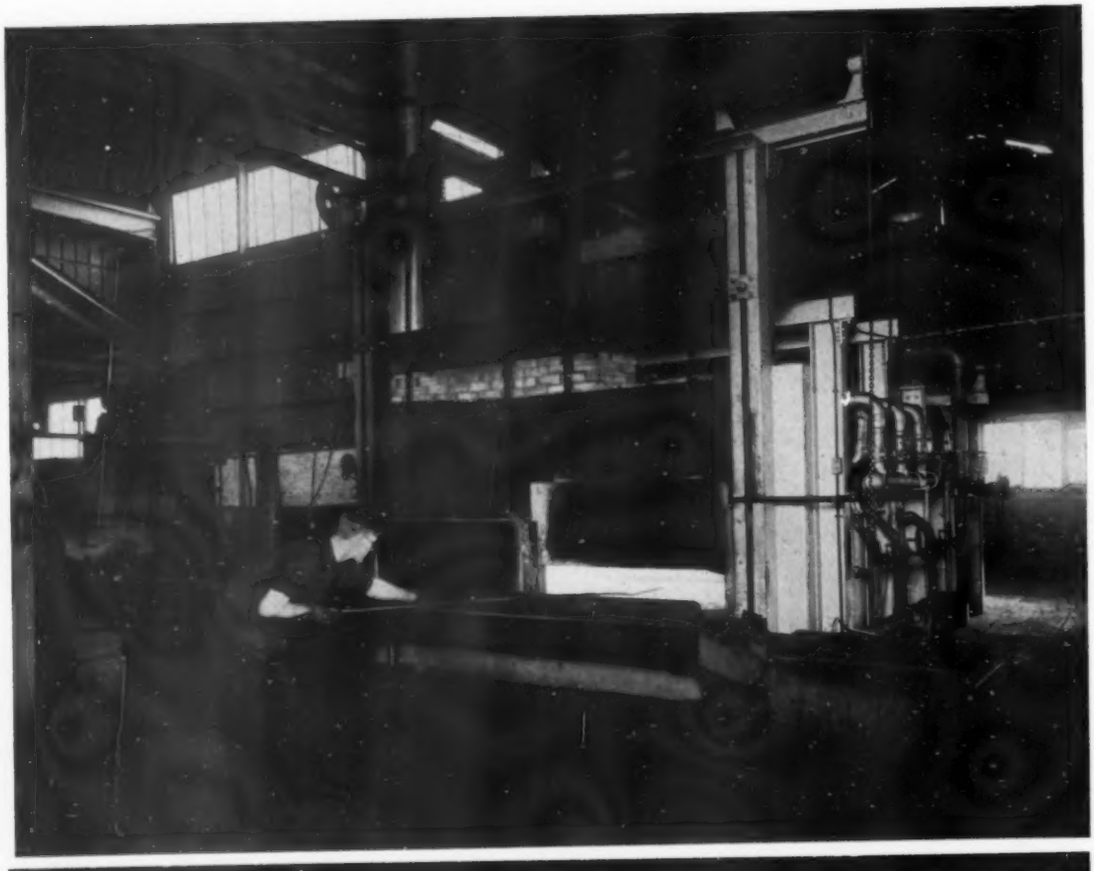

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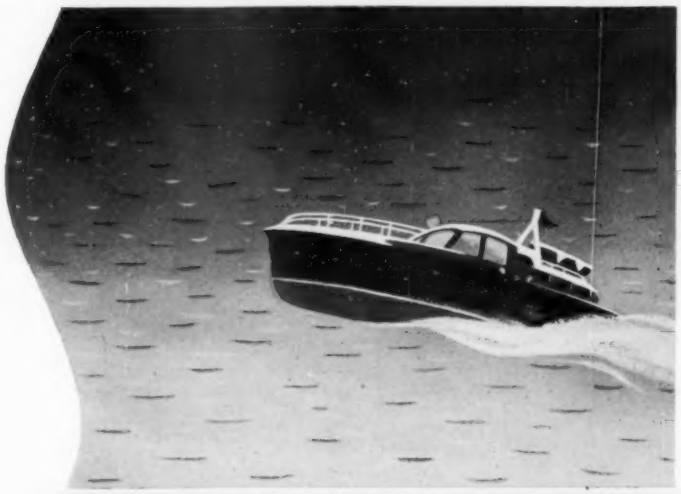

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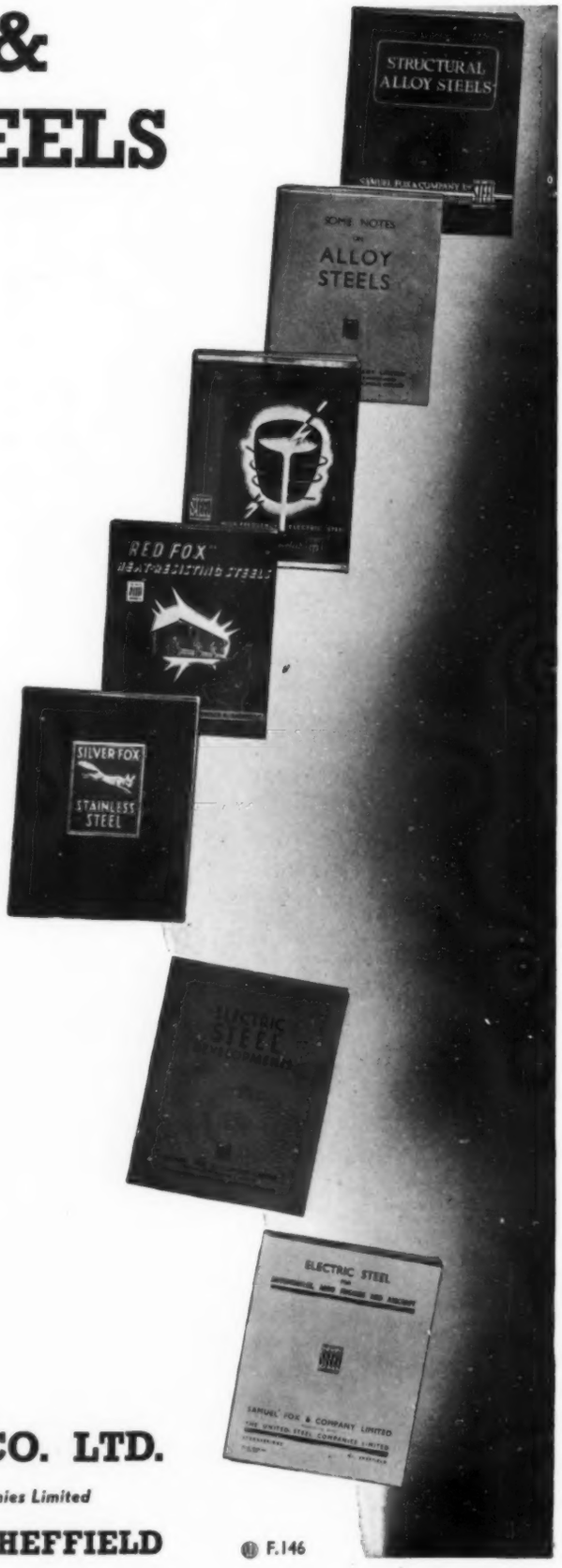

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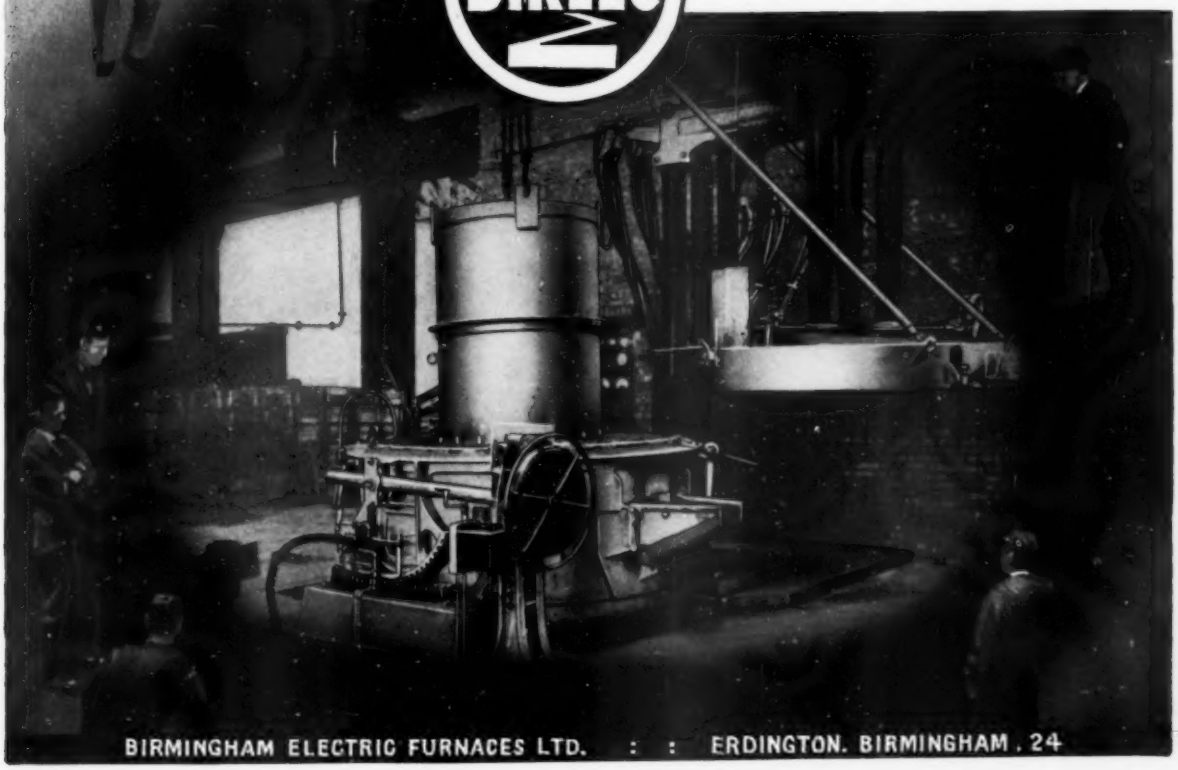

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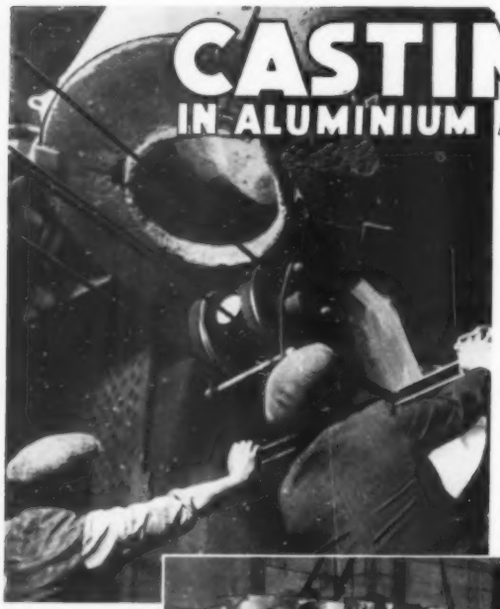

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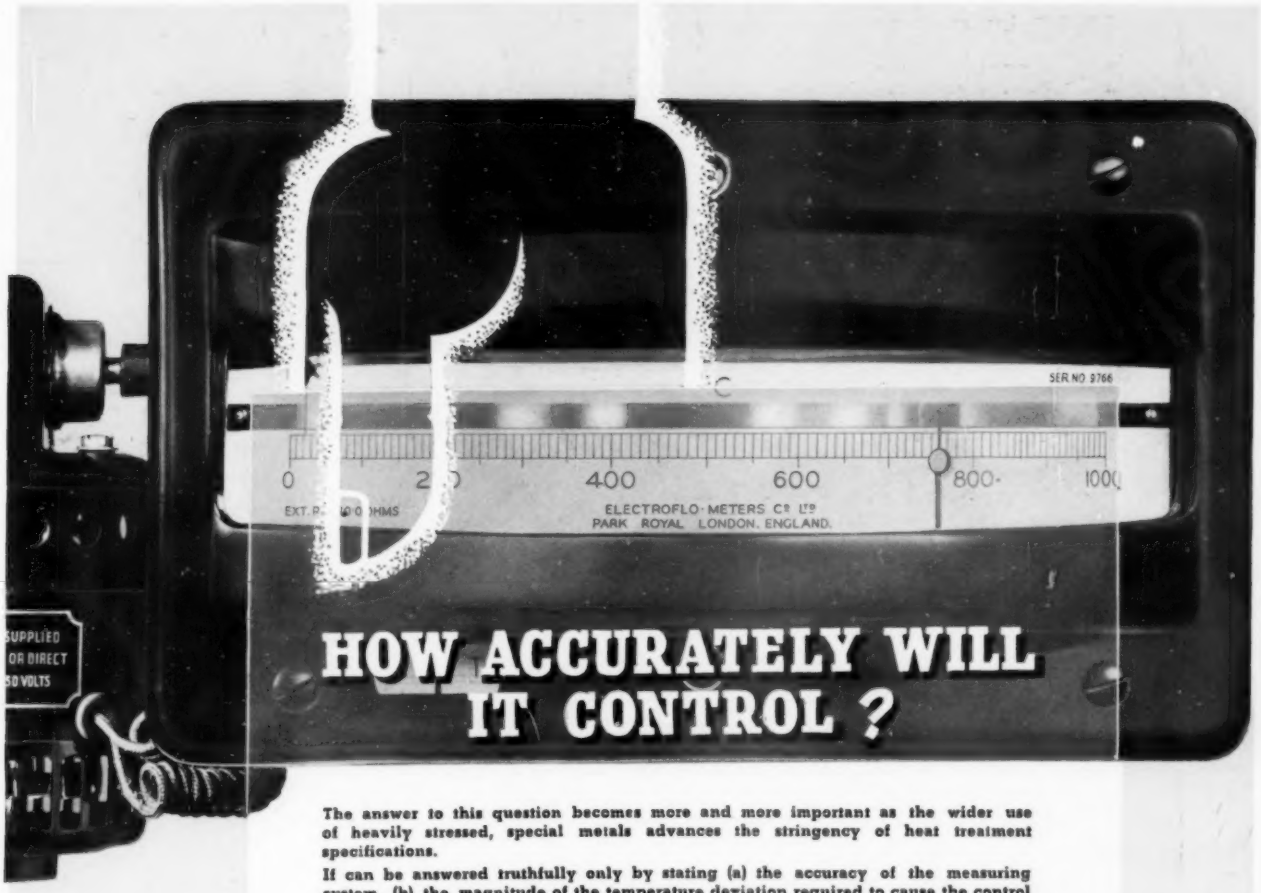

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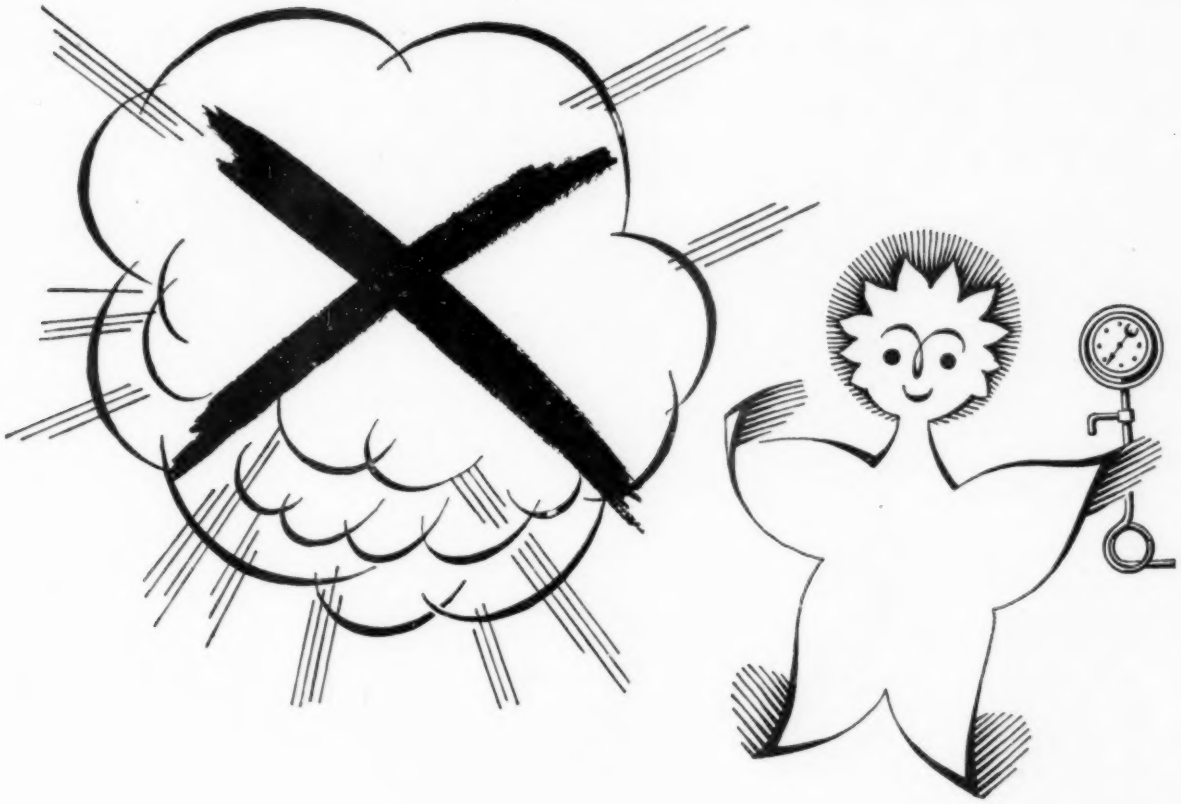

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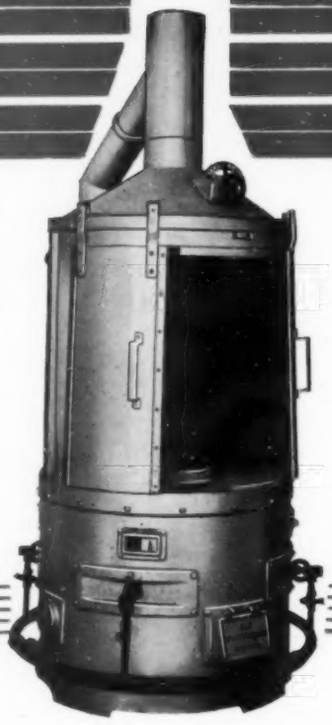

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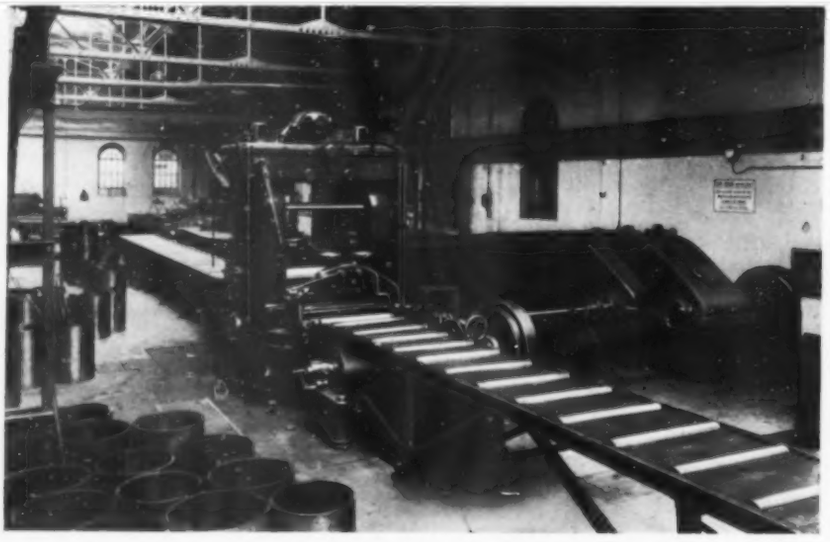

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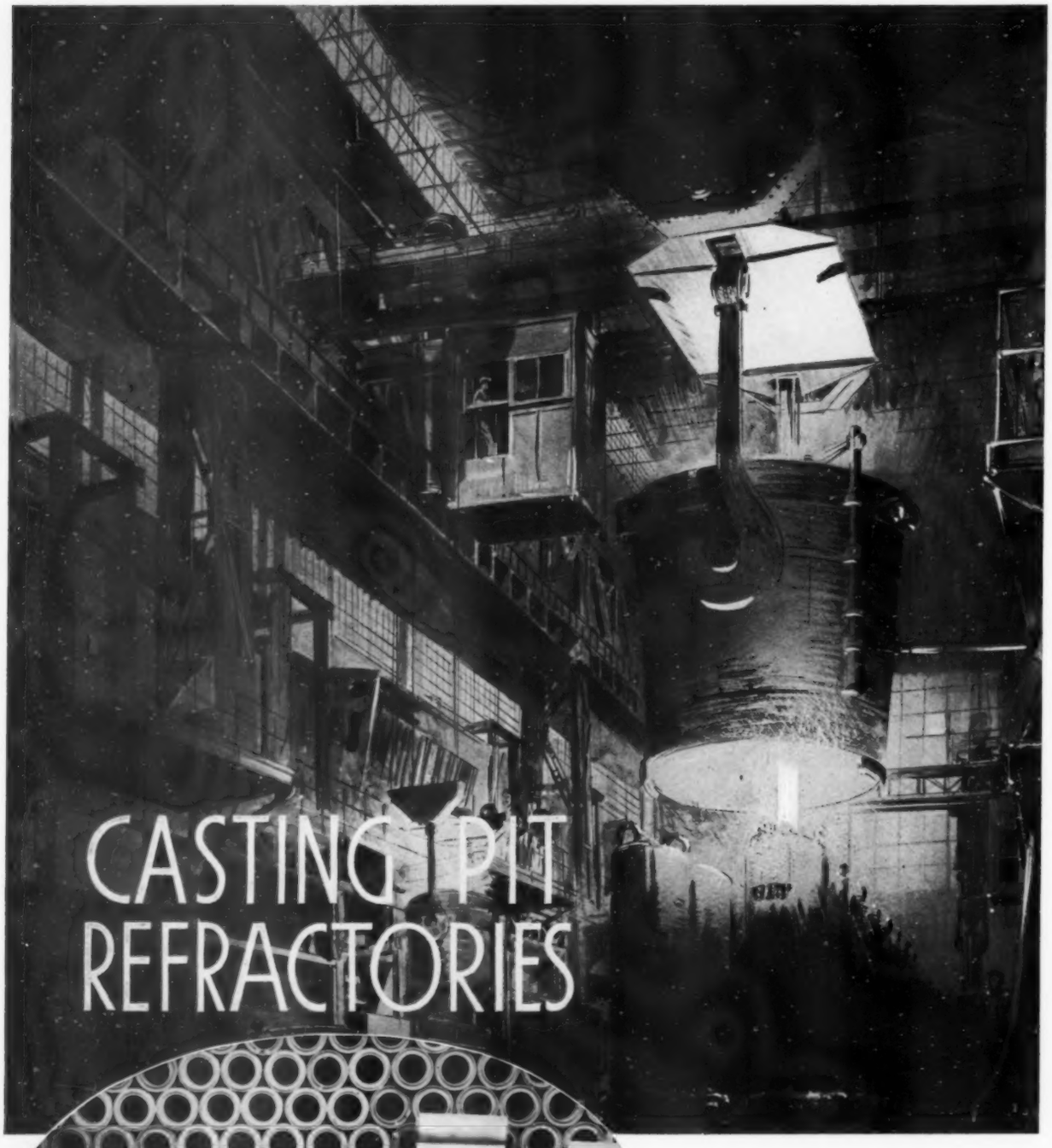

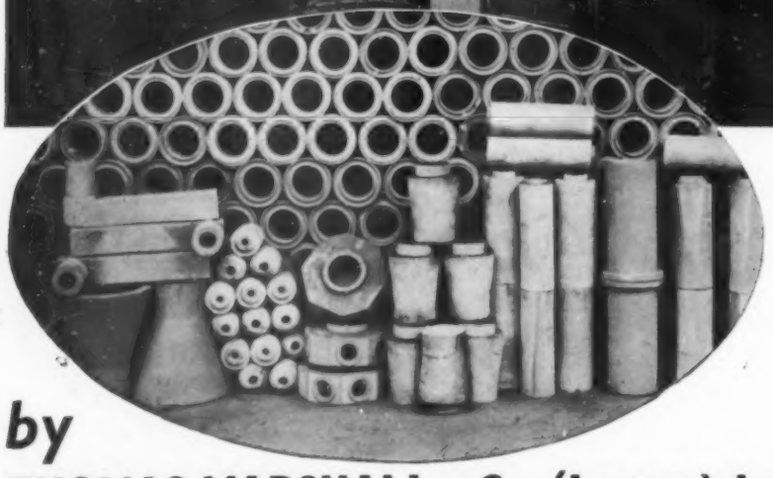

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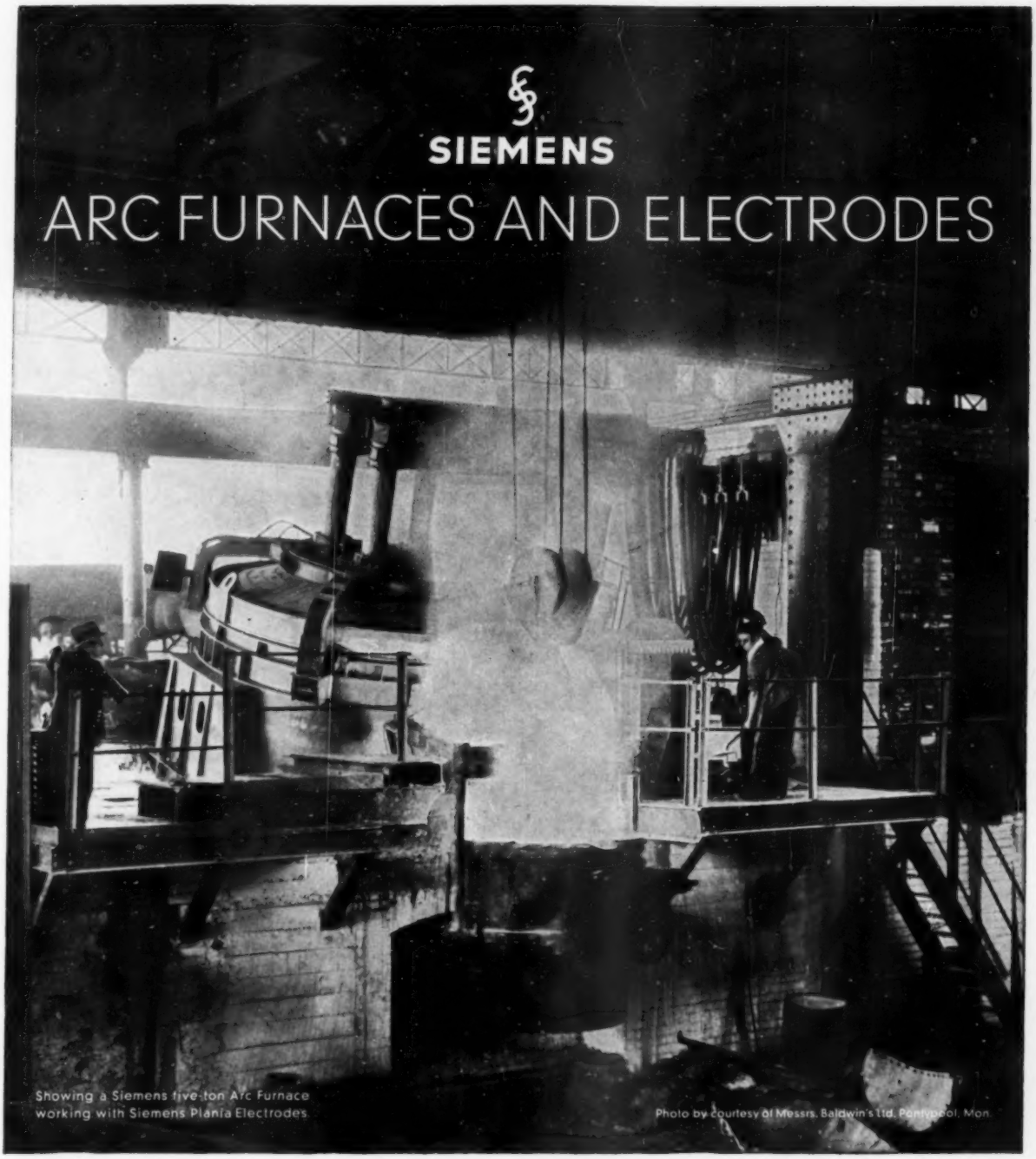
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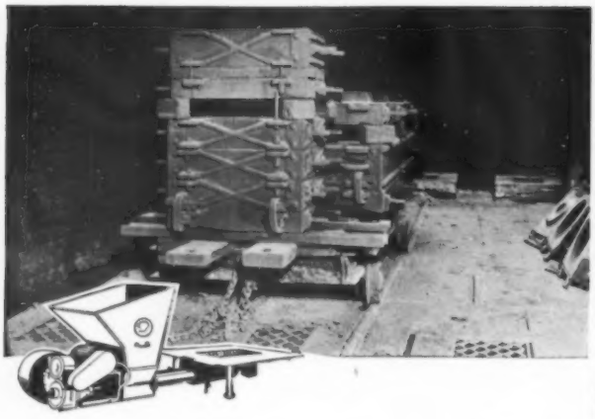

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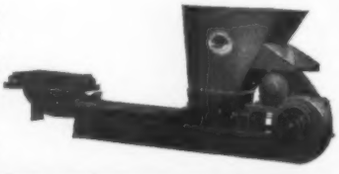

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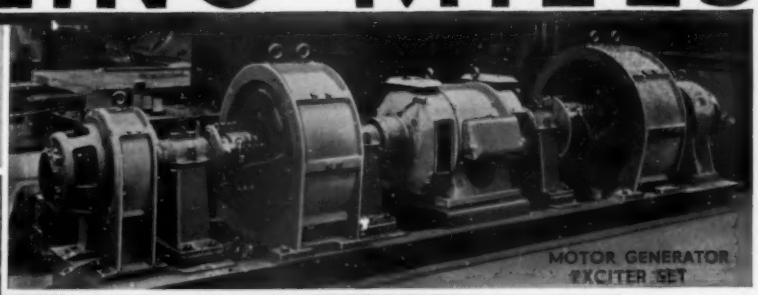

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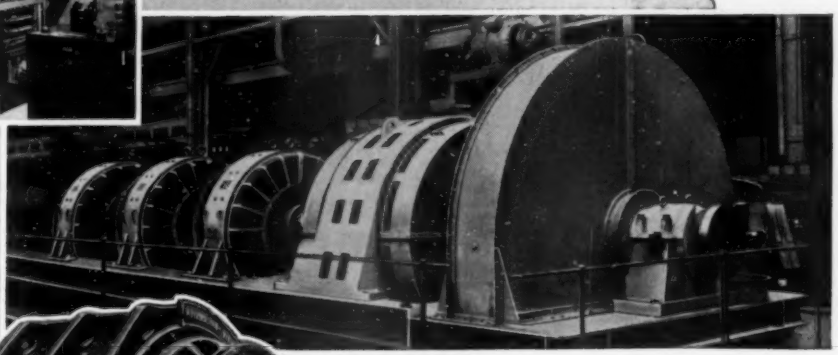

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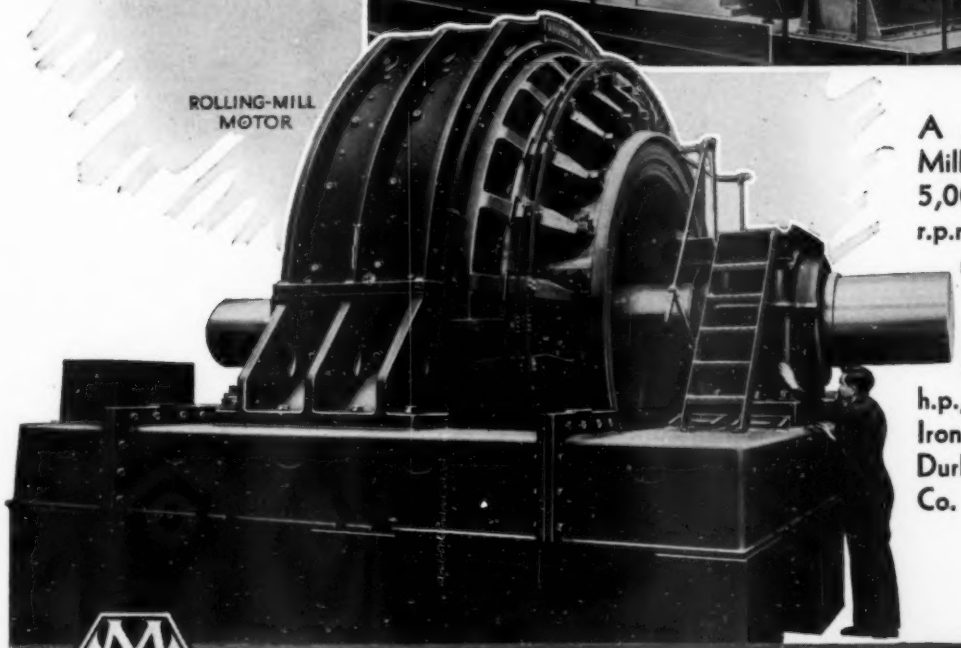

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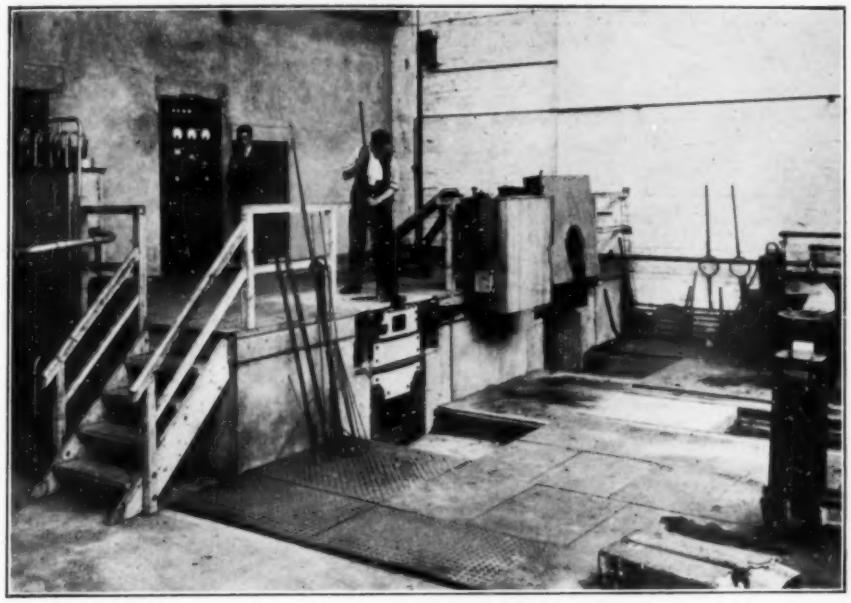

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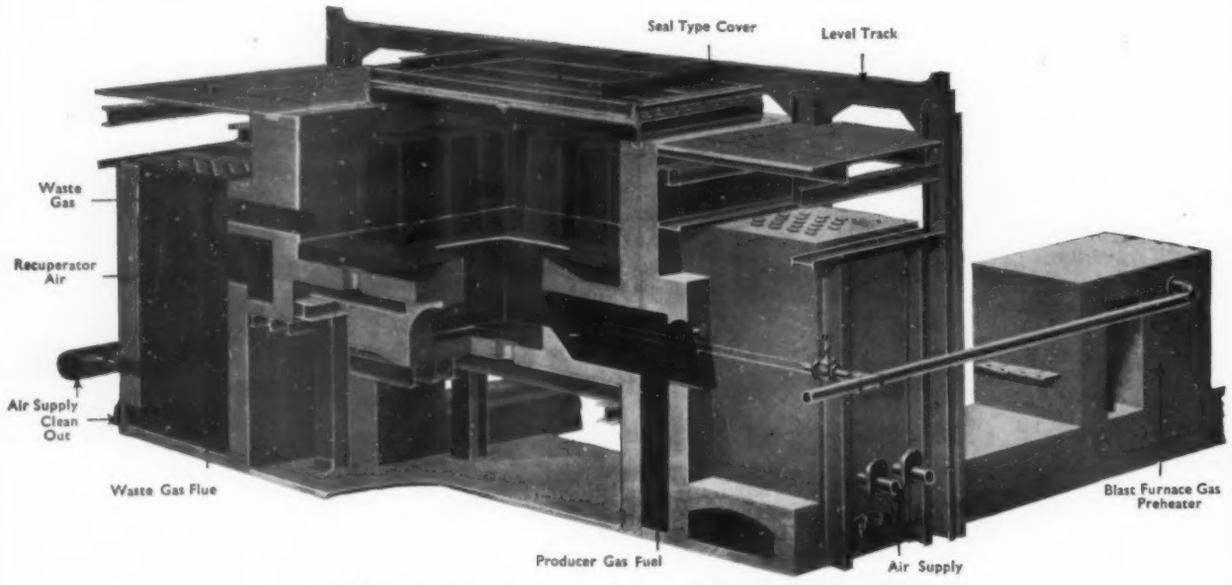

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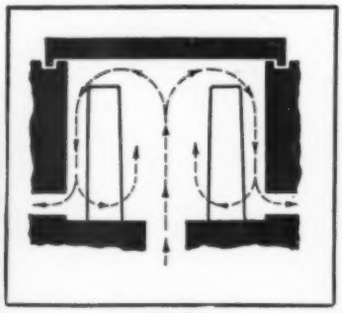

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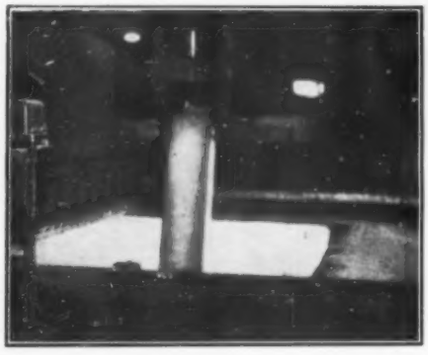

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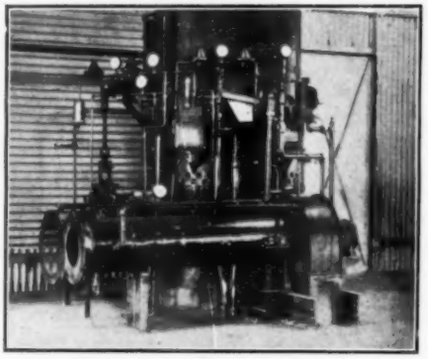

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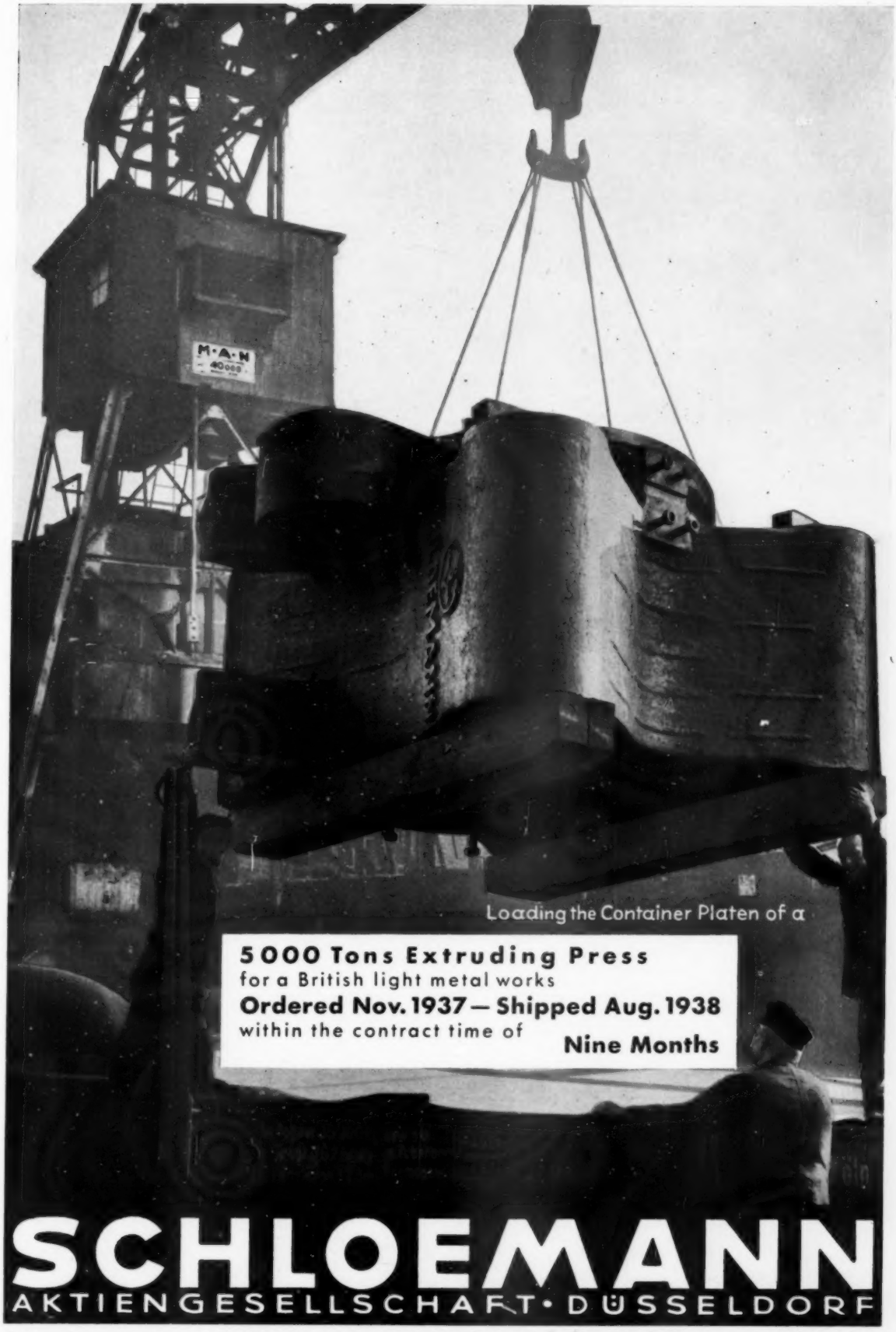

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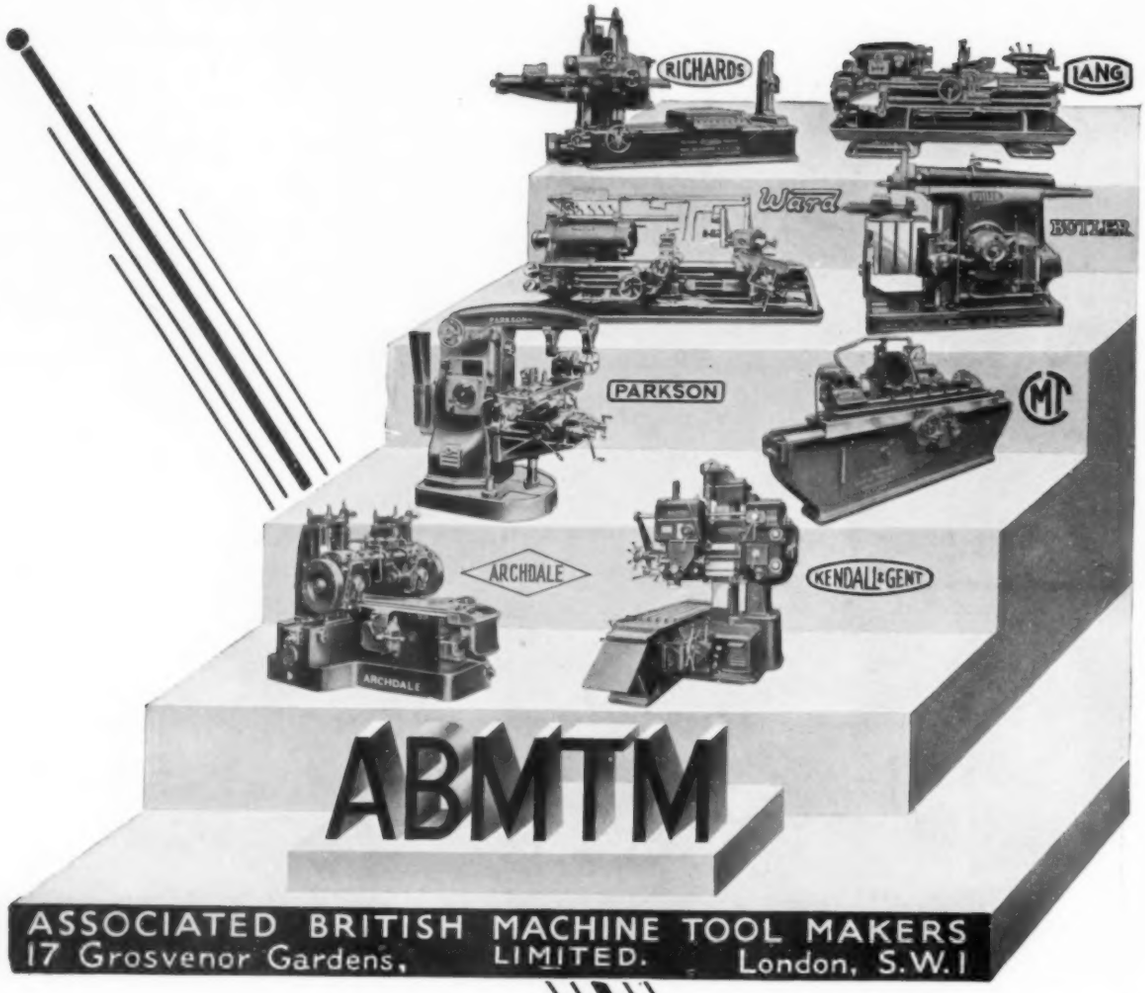

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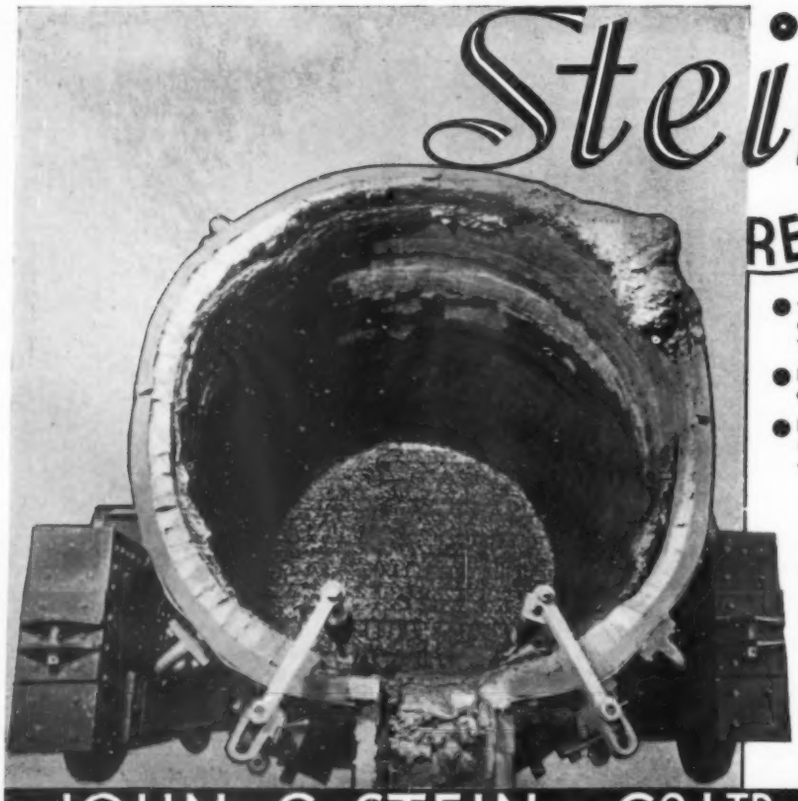

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METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

OCTOBER 1938. VOL. XVIII, No. 108.

Some Applications of High-Strength Aluminium Casting Alloys

By a Special Contributor.

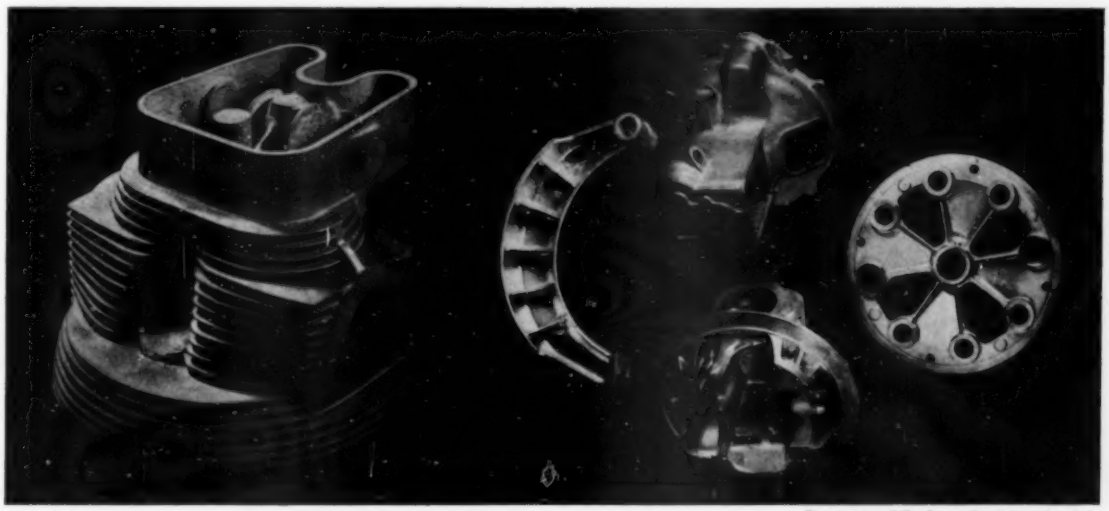
Fields for the further application of high-strength aluminium alloy castings are briefly reviewed. Attention is directed to newly developed alloys for which increased applications may confidently be expected. In addition to the scope offered by aircraft construction, the high properties of many alloys provide increasing possibilities in the general engineering field.

THE advances which have been made in the past few years in the metallurgy of aluminium casting alloys have been reviewed from time to time, and it is the object of the present article to indicate the direction in which the applications of the newly developed alloys may be expected. The appended table shows the tensile properties called for in current specifications covering high-strength aluminium casting alloys.

In Aircraft

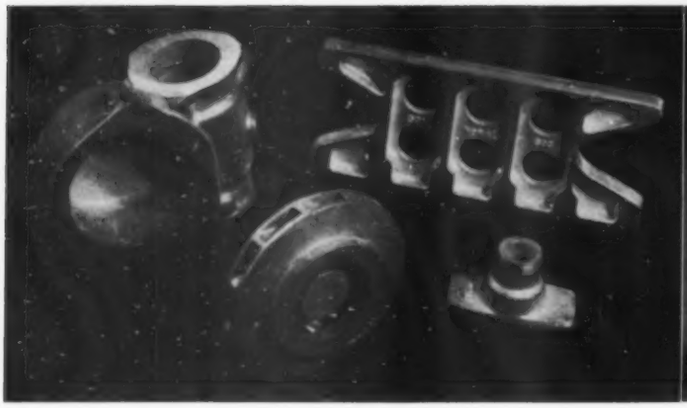
The first and most obvious field for development is in aircraft, where the importance of employing the material which most favourably meets the demand for strength and lightness transcends any consideration of cost. Yet, strangely enough, it is in this field particularly that high-strength light alloy castings may be utilised to effect economy of cost, as well as of weight; and in certain instances light alloy castings may well be employed for convenience and cheapness of assembly in spite of a possible slight increase in weight. Parts which are normally made up from wrought metal in the form of forgings involving costly dies, or are built up from sheet and extrusions, with considerable expense in machining and welding, may be cast in high-strength light alloy. Tube sockets, junction plates and brackets, and levers are instances of such applications. The principal requirements here may not be ultimate tensile strength so much as stiffness combined with ease of assembly. Where parts are subject to shock, and where local stresses may be set up due to sudden changes of section, the choice of material will fall on an alloy with a high elongation, such as NA 226 to Specifications DTD.298 or 304, NA 350 to DTD.300 or Aeral A; or even, where stresses are very low, Alpax. In the event of such local stresses exceeding the designed strength of the component as a whole, the material will then be able to give slightly without fracture occurring. This slight distortion (which ensues as soon as the metal is subjected to stresses beyond the elastic limit) may be sufficient to reduce the local stresses which cause it, and thus restore the structure to equilibrium.

In parenthesis, it must here be emphasised that the intrinsic stiffness of a material depends solely on its modulus of elasticity; and the stiffness of a member made of a given material depends on the moment of inertia of that member and the modulus of elasticity of the material. Very little variation is observable in the modulii of elasticity of aluminium alloys, although their ultimate tensile strengths, elastic limits and elongations vary considerably. If, therefore, the limiting factor is stiffness (that is, the amount by which a member may temporarily stretch or deform under *normal* loading) there may be no advantage in using a high-strength material. It is when momentary excess loadings must be guarded against that alloys with high elongation (i.e., capable of acquiring an appreciable permanent set without fracture) are necessary. Since cast-aluminium alloys with high elongation have only recently



By courtesy of Northern Aluminium Co., Ltd.

Aluminium alloy castings for highly stressed parts, including a cylinder head, brake shoe, gear housing, differential cover and clutch plate.



Some high-strength aluminium alloy castings, including a rear axle housing, an impeller, and a tube stay bracket.

By courtesy of Northern Aluminium Co., Ltd.

The deformation of the left-hand casting demonstrates the ductility of NA.350 alloy.

become available, it is in parts subject to shock that castings are given new scope.

Where the maximum rigidity under normal loading is not required, the ruling consideration will be the adoption of the thinnest possible section, which depends largely on the ultimate tensile strength of the material. Such alloys as RR53c, Ceralumin C, RR53 and Alpax Gamma fulfil the latter conditions, whilst NA226 to DTD361 and DTD.304 provides in addition a guaranteed elongation which may take care of unforeseen local stressing beyond the elastic limit.

The actual forms of application of high-strength aluminium alloys in aircraft are difficult to classify in view of the high degree of specialisation in aircraft design, but enough has been said to indicate the extent to which these may be utilised, and to point out the ruling considerations in the choice of alloy. It remains to review the possibilities of development in the general engineering field.

TABLE SHOWING TENSILE PROPERTIES CALLED FOR IN SPECIFICATIONS COVERING HIGH-STRENGTH ALUMINIUM CASTING ALLOYS

Alloy Designation.	Relative Specification.	Form.	Specified Tensile Properties.		
			0·1% Proof Tons/Sq. In.	U.T.S. Tons/Sq. In.	Elongation % on 2 in.
NA 226	DTD 361	*S	20	21	1
		*C	22·5	26	4
RR 53C	DTD 309	S	18	19	—
		C	19	22	—
Ceralumin "C" ...	DTD 255	S	17·5	18	—
		C	20	23·5	—
RR 53	DTD 131A	S	15·5	16	—
		C	19	20	—
NA 226	DTD 304	S	14	18	4
		C	17	24	9
NA 222	DTD 269	S	13	18	—
		C	14	19	—
Alpax Gamma.....	DTD 245	S	13	15·5	—
		C	16	19	—
"Y" Alloy	B88 L 35	S	13	14	—
		C	14	18	2
Ceralumin "D" ..	DTD 250	S	11·5	14	—
		C	13	20	5
NA 350	DTD 300	S	11	16	7
BA/29		C	13	18	12
NA 125	DTD 276	S	11	15	—
		C	13	17	—
NA 226	DTD 298	S	11	14	7
		C	15	18	10
Aeral "A"	DTD 294	S	11	14	3
		C	12	17	5

* S indicates "Sand Cast." * C indicates "Chill Cast."

The above table includes all current specifications covering alloys for which 0·1% proof stresses of over 8·5 tons/sq. in. are to be expected on 1 in. diameter sand-cast test-bars.

General Engineering

In general, there are four main considerations that may call for the adoption of aluminium alloys:

(1) The lightness of all aluminium alloys.
(2) The high strength-weight ratio of the strong alloys.
(3) Good corrosion resistance (which is characteristic of most alloys, and is very marked in some alloys, of which a few, notably NA350, have high strength).
(4) High thermal and electrical conductivity.

These features and many others associated with aluminium alloys are well known, and advantage has been taken of one or more of them in most branches of engineering.

In nearly all forms of transport the reduction of dead-weight is desirable, and has been achieved in some measure by the use of light alloys. Here, however, the greater first cost of reducing weight has been allowed so far to influence designers too much, and it is felt that ultimate economy by increase of efficiency can be achieved by the far more extensive utilisation of light alloys.

Strong alloys, both wrought and cast, are widely used in commercial vehicles, and in the foremost makes of racing cars and motor-cycles, so that, on the grounds of both economy and efficiency of operation, it is safe to predict still wider adoption in the future. Crank cases, steering boxes, corner posts, differential housings and gear boxes are a few items chosen at random that suggest themselves for manufacture in light alloy to reduce deadweight. Aluminium alloy cylinder blocks show the added advantage of high-thermal conductivity, which has also secured the adoption of aluminium cylinder heads for an increasing number of mass-produced motor-car engines. Cylinder heads and blocks and unit construction of crank cases and gear boxes in light alloy have been successful in motor-cycles. By virtue of the consequent reduction in inertia forces, and the favourable thermal conductivity obtainable with aluminium alloy pistons, these are almost universally adopted for internal combustion engines. Light alloy connecting rods also may be the rule before long.

In railway rolling stock, and particularly in tube trains and rail cars, the modern trend is towards light construction. Here additional advantages are in longer life, greater safety and silence, and a higher recovery value when the units become obsolete.

In shipbuilding aluminium has already found a place, and the high corrosion resistance of Alpax has secured its adoption for covers and unstressed parts. The same alloy is employed for gear casings, coolers, turbine casings, inspection covers, hand-wheels and other marine engine parts in which stresses are low, whilst Alpax Beta and Alpax Gamma are used where greater strength is required. Supercharger impellors for marine and stationary engines may be cast in light alloy, NA226 being particularly suitable in view of the considerable centrifugal loads involved in the running up of such components at high speed.

Birmabright, in both wrought and cast form, has been used in lifeboats and in motor torpedo boats. The most promising alloy for deck fittings and stressed parts is, however, NA350, the strength of which permits of its substitution for Admiralty bronze, gun-metal and malleable cast iron, with little modification in design; and its corrosion resistance, particularly in the presence of brine, is remarkable.

It is well known that aluminium wire reinforced with steel is used for overhead electrical conductors, and a specially developed high-strength alloy, NA305, has been in service for some time in cast conductor clamps. In covers and bulky moving parts for switchgear, aluminium alloys, again notably NA350, have found a place, and NA350 has been adopted for overhead collector arms and pole bases for tramcars and trolley buses

In the chemical and textile industries various aluminium alloys are used for their resistance to corrosive attack, and while the actual alloy adopted varies with the nature of the chemical with which it comes in contact, pure aluminium is likely to retain its pre-eminence.

The printing industry would seem to offer great scope for the adoption of light alloys for moving parts, so that inertia may be reduced and speed of operation increased. American and Continental practice in this respect is in advance of our own, and few British machines incorporate much light alloy, although in certain instances inking frames and various gear covers are of Alpax or M.V.C. alloy.

Ventilating fans, large and small, have been cast in light alloy, and engineers of this industry are quick to take advantage of the economy and increase in efficiency obtained by this method of production. Moreover, the resistance of aluminium alloys to the attack of certain types of corrosive vapour indicate a widening field of application in this branch of engineering.

In architecture aluminium finds its chief employment as a medium for decoration, and the properties specially desired are resistance to atmospheric corrosion and amenability to anodic oxidation in colour finishes. Where, in addition, high strength is required, there are alloys to meet the demand.

It is not possible in the scope of this short article to do more than refer briefly to the directions in which the use of light alloys may be expected to develop. In each branch of each industry there must be countless opportunities to take advantage of the particular properties associated with one or other of the available aluminium alloys, and designers would do well at least to consult the many firms whose specialised knowledge might solve for them specific problems.

The Properties of High Purity Aluminium

A series of measurements on electrolytically refined aluminium of 99·996% purity are discussed. Various tests were made with a view to the determination of the melting point, diffraction patterns, density, electrical resistivity, and certain mechanical properties, the results of which are described.

THE production of pure aluminium by the Hoopes electrolytic process was made in 1925, and simultaneously a paper[1] was published giving data on many of the physical properties of this new high-purity metal. Of the physical measurements reported at that time, not all were made on metal of the same purity, nor even of the highest purity available—namely, 99·99%. Recently aluminium of even higher purity has been produced by a similar electrolytic process, and in the research laboratories of the Aluminium Company, C. S. Taylor, L. A. Willey, D. W. Smith, and J. D. Edwards[2] have made a series of measurements on electrolytically refined aluminium which has a purity of 99·996% aluminium, and where all the determinations were made on metal of the same carefully analysed composition. In preparing the metal for the various tests, the high-purity metal was remelted in a graphite crucible and cast in the form of a sheet ingot, 1·5 in. thick. After cold-rolling to a thickness of 1 in., the surface of the slab was removed by machining, and the sheet then further cold-rolled to produce specimens of a size suitable for the various determinations.

The melting-point was determined with a platinum-rhodium thermocouple calibrated by determining the melting-point of the Bureau of Standards standard sample of aluminium, and was found to be 660·2° C. Thermal expansion was measured by an interferometric method capable of measuring changes in length of 0·00001 mm. Measurements were made on three different test specimens, and the average linear coefficients of thermal expansion for the temperature ranges 20 to 100, 20 to 200, 20 to 400, and 20 to 500° C., determined as $23{\cdot}8 \times 10^{-6}$, $24{\cdot}7 \times 10^{-6}$, $25{\cdot}7 \times 10^{-6}$, $26{\cdot}7 \times 10^{-6}$, and $27{\cdot}7 \times 10^{-6}$, respectively.

Back reflection X-ray diffraction patterns were made from two specimens on one plate. The test specimens were $\frac{1}{2}$ in. × $\frac{1}{2}$ in. × $\frac{1}{4}$ in., and were annealed in a salt-bath for 4 hours at 200° C. The temperature of each sample during exposure was determined by a two-couple thermo-pile and a potentiometer, and the maximum variation in temperature during a given exposure was found to be ± 0·1° C., a variation which would cause negligible variations in lattice parameter, since a thermal coefficient of expansion of 23×10^{-6} would yield a change in parameter of slightly less than 0·0001 A.U. per 1° C. The diameters of the diffraction circles were measured by means of a micrometer-comparator to an estimated accuracy of ± 0·02 mm.; and the distance between specimens and plate to an estimated accuracy of ± 0·01 mm. The result of the measurements on the two specimens gave the lattice parameter of 99·996 purity aluminium as 4·0413 ± 0·0001 A.U. at 25° C.

The density of the high-purity aluminium as calculated from the measured value of the lattice parameter was 2·6953 gm./cc. at 20° C., a value slightly lower than the value determined by the usual weighing method. The density of small samples of 14-gauge sheet annealed by heating for 4 hours at 200° C., determined by the method of hydrostatic weighing, gave the following results :—

Density at 25° C., 2·6978 grms. per c.c.
,, 20° C., 2·6989 ,,

The electrical resistivity of 99·996 aluminium was determined with strips of 14-gauge sheet, 1 in. wide, 24 in. ong, held in a constant temperature oil-bath regulated to ± 0·02° C. and placed in series with a standard resistance of 0·001 Ohm. The resistivity was measured by comparing the potential drop across the standard resistance and across a measured length of the test specimen, when a current of 5 amperes was flowing through both. By means of measurement at two temperatures, the temperature coefficient of resistance was determined. The resistivity temperature coefficient and several other related constants were determined as follows :—

Volume resistivity in microhm-cm at 20° C.	2·6548
Volume per cent. electrical conductivity	64·94
Mass resistivity in ohms (meter, gramme) at 20° C.	0·07165
Mass per cent. conductivity	213·92
Constant mass temperature coefficient of resistance at 20° C.	0·00429

Certain mechanical properties were determined on specimens of 14-gauge sheet cut across the direction of rolling. The determinations were made on three specimens of the cold-rolled material (75% reduction) and on three specimens of the material which had been annealed for 4 hours at 200° C. As it had been previously shown that recrystallisation began at room temperature with cold-work aluminium having a purity of 99·998% aluminium,

1 Trans. Amer. Electrochemical Soc., 1925, Vo. 47, p. 287.
2 *Metals and Alloys*, 1938, Vol. 9, No. 8, pp. 189-192.

the specimens of cold-rolled material were tested within an hour of rolling to avoid any appreciable softening. The results of the tests were :—

Condition.	Yield Point.* Tons/sq. in.	Max. Stress. Tons/sq. in.	Elongation. % on 2 in.	Brinell Hardness.
Cold rolled	6·44	7·28	5·5	27
Annealed ..	0·79	3·07	48·8	17

* For a permanent set of 0·2%

As aluminium of the high purity tested is very susceptible to grain growth during annealing, and as coarsening of the grain has an important effect on both tensile strength and elongation, the mechanical properties being influenced in an important way by grain structure are no intrinsic function of purity. The annealed samples tested had what might be called a medium grain size.

Reflection and emissivity measurements were made on samples of the high-purity aluminium sheet, samples of which were electrolytically brightened in order to develop maximum reflectivity. The reflectivity—that is, the total reflection for light from a tungsten filament lamp—was determined and found to be 90%. Aluminium films formed by the vapourisation of aluminium and condensation in vacuo have shown by the same method of testing reflectivities only slightly higher.

The thermal emissivity of a specimen of 99·996% aluminium held at a temperature of 37·5° C. (100° F.) was determined by means of a sensitive radiometer. Using a value of 5% for the emissivity of bright aluminium foil having a purity of 99·5%, this high-purity aluminium was found to have an emissivity of 4·5%. A survey of published data indicated that the emissivity of bright commercial foil might be as low as 3%, in which case the value for the pure aluminium would be 2·6%, but as no established standard of low emissivity was available, the figure of 5% for the emissivity of the foil was used in calibrating the radiometer.

New Metallurgical Laboratories at Sheffield University

CONSIDERABLE interest is attached to the recent official opening of the new metallurgical laboratories at Sheffield University, in that one of the University's most distinguished honorary graduates, Sir William Bragg, played the leading role in the proceedings. In declaring open the new laboratories, Sir William said Sheffield steel was to be found all over the world, and Sheffield's name went with its steel. Whatever were the causes of Sheffield's first devotion to the manufacture of steel, it was clear that her present reputation depended both on the technical skill of her manufacturers and men, and on her belief in the value of metallurgical research. In the development of these laboratories the citizens of Sheffield had been pioneers in a most noteworthy instance of the direct application of scientific research to industry.

The new building forms part of the Metallurgical Department, and is the first part of the new building scheme. The rebuilding and reorganisation of these metallurgical laboratories has been made possible largely by the generosity of Sir Robert Hadfield, Bt., D.Met., F.R.S., who contributed £20,000 of the £30,000 required. This gift, and earlier gifts to the Department, is commemorated by the naming of the new laboratories after him. Regret was expressed by the Senior Pro.-Chancellor of the University, Sir Henry Stephenson, Bt., that Sir Robert was unable to be present at the opening owing to ill-health.

Professor J. H. Andrew, Dean of the Faculty of Metallurgy, paid tribute to Sir William Bragg and his son for their work in developing new lines of thought in the science of metallurgy. He commented on the beautifully panelled meeting room, which is regarded as a feature of the new building. The panelling had been provided by Mr. John Ward, treasurer of the University and chairman of the Applied Science Committee.

Forthcoming Meetings

IRON AND STEEL INSTITUTE.

Oct. 26. Autumn Meeting, at the Institution of Civil Engineers, Great George Street, Westminster, S.W. 1, at 10 a.m. and 2-30 p.m.

STAFFORDSHIRE IRON AND STEEL INSTITUTE.

Nov. 8. "Symposium on Steelmaking." Discussion by Dr. Sargent and Dr. T. Swinden.

INSTITUTE OF METALS.

Oct. 27. Autumn Meeting, at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W. 1, at 10 a.m. and 2-30 p.m.

BIRMINGHAM SECTION.

Nov. 3. Open Discussion on "The Training of a Metallurgist."

LONDON SECTION.

Nov. 10. "Electron Diffraction and Surface Wear," by Prof. G. I. Finch, M.B.E. Meeting at Royal School of Mines, South Kensington, S.W. 7, at 8 p.m.

NORTH-EAST COAST SECTION.

Nov. 8. "Relationship between Mechanical Properties and Results in Service," by L. W. Schuster, M.A.

SCOTTISH SECTION.

Nov. 14. Visit to the Works of Glenfield and Kennedy, Ltd., Kilmarnock, at 8 p.m.

SHEFFIELD SECTION.

Nov. 11. "The Expert Use of the Microscope," by H. Wrightson, B.Met.

SWANSEA SECTION.

Nov. 8. "Copper Alloys and their Adaptation to Modern Engineering Requirements," by H. J. Miller, M.Sc.

MANCHESTER METALLURGICAL SOCIETY.

Oct. 19. "Some Researches into the Mechanism of Corrosion," by U. R. Evans, M.A., D.Sc.

Nov. 2. "Quantitative Spectrographic Analysis," by D. M. Smith, A.R.C.S., B.Sc.

ROYAL AERONAUTICAL SOCIETY.

Oct. 20. "The Use of Light Alloys in Aircraft Construction," by M. R. le Coeuvre.

Nov. 9. "American Aircraft," by T. P. Wright, F.I.Ae.S., F.R.Ae.S.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Nov. 4. "Chilled Iron and Other Rolls," by A. Allison.

EAST MIDLANDS BRANCH.

Oct. 22. "Recent Researches in Foundry Coke," by H. E. Blaydon.

LINCOLNSHIRE SECTION.

Nov. 4. Joint Meeting with Lincoln Engineering Society. "Recent Improvements in Cast Iron," by J. E. Hurst.

LANCASHIRE BRANCH.

Nov. 5. "Foundry Drying and Modern Core Shop Layout," by W. H. Smith.

BURNLEY SECTION.

Nov. 8. "Melting Practice in the Foundry," by S. E. Dawson, F.I.C.

LONDON BRANCH.

Nov. 2. "What we do not know about Cast Iron," by J. E. Hurst.

EAST ANGLICAN SECTION.

Oct. 20. "Report of Cast Iron Sub-Committee on the Properties of Grey Cast Iron," presented by A. B. Everest, Ph.D., B.Sc.

MIDDLESBROUGH BRANCH.

Oct. 21. "Report of Cast Iron Sub-Committee on the Properties of Grey Cast Iron," presented by E. B. Ellis.

NEWCASTLE-ON-TYNE BRANCH.

Oct. 20. "Ironfounding in Hong Kong," by S. Simpson.

SCOTTISH BRANCH.

Nov. 12. "The Making of Large Lathe Beds," by W. Y. Buchanan.

FALKIRK SECTION.

Nov. 5. "Facings in Use in the Modern Foundry," by H. Winterton.

BRISTOL SECTION.

Nov. 12. "Non-Ferrous Castings," by C. A. Howe.

WEST RIDING OF YORKSHIRE BRANCH.

Nov. 12. Visits to the Works of R. W. Crabtree and Co., Ltd., and to the Crabtree Foundry Co., Leeds.

METALLURGIA
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Industrial Management

FOR some reason, not readily apparent, training for the responsibilities of management has been frowned upon in this country ; with many notable exceptions, the tendency is to rely on what is sometimes referred to as the " muddling through " process, without a full recognition of the economic advantages of efficient management. But the subject of management and its economic value industrially is not by any means new ; industry has been controlled, to some extent, since this country became industrialised. In those early days, however, conditions were not so exacting and competition not so acute as to-day, and the knowledge necessary to success in the management of a factory or an industry was not then so great. Almost every field of industrial activity has been the subject of continued study, but training for efficient management appears to have been overlooked, except in a few foreign countries like the United States and Germany, which have for many years appreciated the importance of giving it close study.

Apart from its application in a strict industrial sense, recent crises have served to demonstrate a strange lack of organisation and management by those in charge of the destiny of this country and of the Empire. Weaknesses were manifest, which seemed to indicate a reprehensible lack of co-ordinated policy and a deficiency in the ability to organise and control in an emergency. Gradually, the political leaders have been forced to recognise that to-day politics are more intimately associated with industry and trade than ever before. They have been driven to protect industries and the employment of British workpeople against unnatural and artificial imports, and have been forced to become parties to preferential tariffs and bilateral trade agreements to reopen to some extent avenues for export trade that have been closed by the interference of Governments with finance and trade in many countries.

In the last few years, for instance, Germany has provided an example of complete economic organisation by control of every phase of economic activity. The basis of the system is the foreign exchange control, which permits the control of foreign trade and of commodity markets. Beyond that, the State also maintains a strict check on supplies and prices and therewith on profit margins. Through the corporate organisation of industry individual profits are utilised for such purposes as export bounties, subsidies to maintain low food prices, and the establishment of unprofitable works for the production of substitute raw materials. Private investment is equally controlled by a strict ban on the formation of new companies and on the extension of plant except with Government permission.

It is not suggested that the doctrine of self-sufficiency, as practiced by Germany, should be applied to Great Britain, because the British people recognise it as a restriction upon progress in wealth and culture, but it should not be overlooked that, by efficient management and control, though lacking many essential raw materials and accumulated savings, Germany has mobilised her economic resources to a point where the only limit to her productive output is set by the total of her employable labour. A surprising feature, however, which is common to those countries practising this doctrine is that while their imports are under very strict control, they claim the right to export their products to countries whose goods they have no desire to buy ; thus other countries, frequently much against their will, are forced to adopt similar control as legitimate defence. The need for keen organising ability in maintaining a balance in these economic manœuvres was never greater than to-day, and with this object it is suggested that the training of politicians in efficient management would be profitable to the country ; it would probably enable the Government to make use of the surplus labour available and to initiate a period of prosperity now that war clouds seem to have been dispersed.

Although politics are now closely associated with commerce and industry, national policies regarding industry are carried out by the cumulative efforts of many separate units, and it is in these individual units that the functions of management are best developed, in which the spirit of friendship and willing co-operation between owners, management and workers can provide a new outlook on management to meet modern conditions. For many years industrial management has been forced to arm itself to face its problems and perplexities ; at first, attention was directed more particularly to economic and technical factors, frequently with a total disregard of the important psychological factor, gradually, however, a better understanding of the relative importance of these factors, essential to the success of industrial management, is being increasingly appreciated and the relations of those engaged in industry are being improved to the general good.

Modern conditions demand that wasteful managerial methods must be displaced by efficient methods, and elsewhere in this issue we publish the first of a series of articles designed to familiarise readers with the modern methods for co-ordinating economic, technical, and psychological factors in an effort to assist in the development of an improved industry. The author is Professor F. L. Meyenberg, who has had over 25 years' industrial experience and eight years' educational and research work as Professor of Industrial Administration and Manager of the " Refa "—the German Institute of Work and Time Studies,—and thus is well qualified to deal authoritatively with the subject of industrial management and production control. Professor Meyenberg is co-author of that very interesting book on " The New Management," recently published by Messrs. MacDonald and Evans, which is full of sound reasoning on industrial management as readers who have read the book will agree. The article in this issue is primarily an introduction to the subject and deals more with theoretical considerations in order that subsequent articles on practical aspects of management and production control will be more readily understood. Attention will be directed more particularly to the ferrous and non-ferrous producing industries, but the subject will be presented in such a way that the principles involved may be applied to particular units or sections of industry.

It is noteworthy that special training for management has been commenced at Sheffield University by the introduction of a new course. The course, which will comprise a series of lectures by Mr. T. G. Rose, M.I.Mech.E., M.I.F.E., F.I.I.A., will be based on a broad survey of the responsibilities that arise in the different management functions.

Institute's Autumn Meetings

CONSIDERABLE disappointment was felt when it became known that the official visit to Canada and the United States of America, arranged by the Iron and Steel Institute and the Institute of Metals, had been cancelled and the autumn meetings postponed. The disappointment was not by any means confined to the two or three hundred members who had made arrangements to participate, but by a great number of members in this country who, although unable to make the tour, recognised the possibilities of such a visit in uniting more closely the English-speaking countries concerned, and the feeling was not less acute in Canada and the United States where a great amount of work had been done to ensure the success of the visit.

It is rather surprising that this is the second time the invitations of the American Iron and Steel Institute and of the American Institute of Mining and Metallurgical Engineers have been unavoidably cancelled, although the first occasion—in 1932—the arrangements had not proceeded very far before a postponement was agreed upon in view of the industrial depression experienced at that time. It is regrettable that the time and expense incurred, here and in Canada and the United States, in making such elaborate arrangements for the tour should have been rendered largely futile; but the political situation at the time was such that no alternative seemed possible, especially as the members directly concerned in the proposed tour were key-men in their respective industries.

It is hoped that the American Iron and Steel Institute and the American Institute of Mining and Metallurgical Engineers will appreciate the gravity of the cause of the cancellation and will extend the invitation at a later date, possibly next year. This would coincide with the New York World's Fair, which will commemorate the 150th Anniversary and the inauguration of America's first President. The close and friendly relations which have so long existed between this country and the United States make it no matter for surprise that the United Kingdom should be represented officially in this Exhibition on a very large scale, and it would provide an exceptional occasion for the renewal of the invitation.

The autumn meetings of the Iron and Steel Institute and the Institute of Metals, jointly arranged to take place in New York on October 3 and 4, and subsequently postponed, have now been arranged to be held on October 26 and 27, respectively. The Iron and Steel Institute meeting will be held at the Institution of Civil Engineers, Great George Street, Westminster, S.W. 1, and that of the Institute of Metals at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W. 1.

Obituary

As our last issue was being distributed we learned with sincere regret of the death of Mr. Richard R. Barclay, O.B.E., at his home in Birmingham. Mr. Barclay had a very wide experience in non-ferrous fields, and occupied many responsible positions in his career. In 1928 he became managing director of Henry Wiggin and Co., Ltd., and in 1931 he was appointed consulting metallurgist to the Mond Nickel Co., Ltd. In 1936 and 1937 he was elected president of the Institute of Metals, a position he occupied with distinction. He possessed a charming personality, which, in addition to his position as an outstanding authority on non-ferrous metallurgy, gained for him a very wide circle of friends, and his death is a great loss to metallurgy and the Institute of Metals in particular.

We regret to announce the death of Mr. Arthur E. Barfield, on September 15, 1938, after a short illness. Mr. Barfield was chairman of Wild-Barfield Electric Furnaces, Ltd., a position he had occupied for many years, and his loss will be keenly felt not only by his colleagues, but by the many friends with whom he came into contact.

Developments at Cleveland Works

DORMAN LONG AND CO., LTD., have recently completed a new coke-oven gas-fired basic open-hearth furnace, which is about to be put into operation. This will be the fourth open-hearth furnace to be put into operation at the North Steel Plant, at Cleveland works, during the past 15 months to operate solely on coke-oven gas. The earlier three furnaces, each of 100 tons capacity, have proved most satisfactory, and the new furnace, though larger, is generally of a similar type. These four furnaces, together with a 400-ton mixer, are operating on straight coke-oven gas from the coke-oven plant erected at these works in 1936.

A new mechanically charged blast furnace, for the production of basic iron, is also in course of erection at these works. It is located in line with two blast furnaces recently reconstructed on modern lines, and will be of similar type and capacity. The furnace is designed to produce 2,750 tons of basic iron per week, which will be delivered to the steel plant in a molten condition. The furnace will be fitted with the latest type mechanical charging equipment, together with the necessary indicating and recording appliances. A large turbo-blower is being installed, and the blast volume and temperature will be automatically controlled.

Methods for Economising Manganese in the Open-Hearth Process

WITH increasing total manganese content in the system, "molten metal-slag," the FeO content of the slag decreases, and thereby also the quantity of oxygen prepared for oxidising the molten metal. A high content of manganese in the charge is therefore, under corresponding working conditions, an efficient medium for keeping the oxygen content of the molten metal low from beginning to the end. This effect of the manganese, however, is important only at the end of the decarburisation because, previously, the carbon of the molten metal decides upon the concentration of oxygen in consequence of its large power of reduction. Under these circumstances it is obviously not economical to introduce into the process great quantities of manganese with the charge, unless it is possible, by suitable methods of melting, to reduce later to a great extent, the manganese which was bound by the slag in the beginning of the process and to bring it back into the molten metal. By using the latter method the finishing of the steel with valuable ferro-manganese is completely superfluous.

According to these considerations a noteworthy economy in manganese should be possible without interfering either with the melting process or the quality of the steel finally produced. That is actually proved by a series of melts produced under industrial conditions in both the acid and the basic open-hearth processes, and described by Peter Bardenhener and Gastar Thanheiser.*

In the first case four melts, each of about 38 tons charge, were investigated, and the results were checked by an independent publication of experiments made in a similar manner at another steelworks. The second case is more complicated, as the report deals with melts treated by the "duplex method"—i.e., melting first in a basic and then in an acid open-hearth furnace. This method had to be adopted because of the lack of raw materials suitable for the pure acid method. This fact, however, has no direct influence on the problem of manganese economy, with which the authors are only concerned. They have given tables and figures and graphs of each of the investigated melts, and draw from their investigation the conclusion: Although the method of working, as explained above, may not be applicable to all open-hearth melting processes, the examples show that a saving in manganese is possible under certain working conditions, and how it can be effected; and it should not be forgotten that this saving is concerned with the highly valuable ferro-manganese, the supply of which is sometimes difficult.

* "Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf," Vol. XX, No. 6.

A System for the Investigation of the Mechanical Properties of Cast Iron

By J. E. HURST

In recent years there has been considerable progress in the development of cast iron; its economic usefulness, however, is largely dependent upon its special mechanical properties, which has led to an intensive study of the various attributes of the strength properties of this material. The usual methods of testing do not give data for all its qualities; for many applications, for instance, it is important to study the elastic characteristics of cast iron. In this article the author describes a system of mechanical testing which could be applied as a basis for acceptance tests.

IT is being realised more and more that cast iron as a material of construction possesses mechanical properties peculiar to itself, and that its application and usefulness in engineering structures is dependent to a very large extent upon these special properties, and they are consequently of vital importance in determining its economic usefulness. This has led to an intensive study of the various attributes of the strength properties of cast iron, and whilst not many years ago the ultimate breaking strength in straight tension and in transverse bending, together with the deflection in transverse bending were almost the sole criteria of its qualities, to-day it is of importance to be able to study the elastic characteristics in as full a manner as possible.

The system of mechanical testing described in these notes is not put forward as a basis for acceptance tests, although in part it is used for this purpose in certain specific applications of cast iron—e.g., centrifugally-cast pipes and cast-iron cylinder liners and piston rings. In spite of this declaration, the author is unable to see any real objection of a fundamental character or any insuperable obstacle which should prevent this system becoming more generally adopted for acceptance tests should it be deemed desirable.

The outstanding advantage of this system lies, however, in its application to research and investigation into the various attributes of the mechanical strength properties of cast irons. The system is based upon the use of annular ring-form specimens, and is, in fact, fairly well known to many who have followed recent investigations. Whilst it has been described frequently in association with the results of various types of investigations, it does not appear to have received separate comprehensive treatment in such a manner that the whole details of the test procedure and the facilities which it affords can be followed readily.

The early development of this system originated in the piston-ring industry, but its more extended development coincides with the developments in the production of castings by the centrifugal process, not only for cylinder liners and piston-ring drums, but also for cast-iron spigot and socket pipe for gas, water and sewage. In the centrifugal casting process the quality and properties of the cast iron are influenced by the centrifugal action in a distinctive fashion. It was realised that this influence could only be demonstrated satisfactorily by means of specimens cut from the actual castings. Centrifugal castings being almost always cylindrical castings, advantage was taken of the methods of testing established for piston rings, and the use of this method on ring-form specimens easily obtained from such castings enabled the study of their properties to be undertaken.

Ultimate Breaking Strength

In its application to the determination of the breaking strength the ring test is used to determine what is described as "the tensile strength." The general form of this test can be understood best perhaps from an extract of the existing material specification in which this method of testing is used. These are the British Standard Specifications for aircraft material, Cast Iron Piston Ring Pots 4K6; and the British Standard Specification for Piston Ring Pots 5004. In these specifications the ring form specimen is used in what is described as a tensile test, and also in an electricity test. The tensile test is carried out in the following manner: A test ring cut from the cylindrical pot casting to an approximately square section, or to a section approximating that of the finished piston ring is split and pulled apart in a testing machine by a load applied at opposite ends of the diameter which is at right angles to that through the gap. The test ring must withstand a stress of at least 16 tons per square inch before fracture calculated from the following formula—

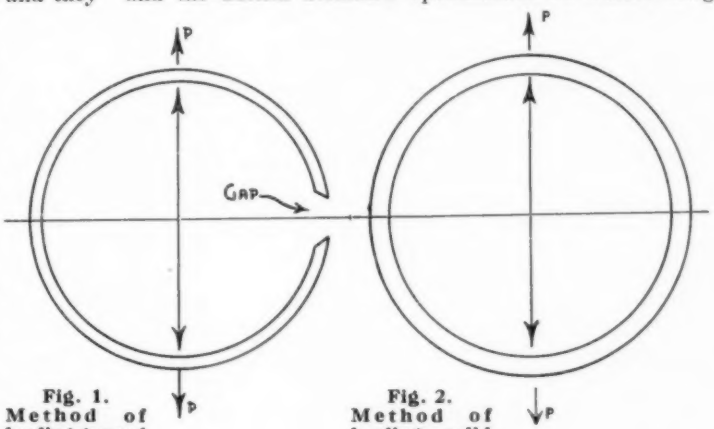

Fig. 1. Method of loading gapped ring for tensile test.

Fig. 2. Method of loading solid ring for tensile test.

$$S = \frac{Pd}{1{,}200\ bt^2}$$

where S = stress in tons per square inch
P = load in pounds
d = external diameter in inches
t = radial thickness in inches
b = width of ring in inches

The manner of applying the load in this test is illustrated by the sketch Fig. 1. The B.S.I. specification No. 5004 incorporates exactly similar provisions, but uses slightly different limits of acceptance values. The form of test used in the British Specifications for centrifugal cast pipe differs somewhat from the above in that the complete test ring is used in the unsplit or ungapped condition. It is required that a ring not exceeding one inch wide shall be cut from the pipe and broken by the application of a load in the manner shown in the sketch Fig. 2. In the specification it is required that the specimen shall show a breaking stress of not less than 15 tons per square inch, when calculated by means of the following relationship—

$$S = \frac{P(D - t)}{4{,}000\ bt^2}$$

Where D equals the mean diameter in inches, the remainder of the symbols having exactly the same significance as those mentioned above.

It is of some general interest to include a note on the derivation of the above relationship. In the case of the so-called "tensile test" in the B.S.I. Specifications 4K6 and 5004 the formula by which the "tensile strength" value S is obtained embodies an empirical relation between the modulus of rupture or extreme fibre stress "f," and the tensile strength as determined by the direct method on straight tensile test bars. Referring to the diagram Fig. 3, in the case of the split ring O X Y stressed by the application of a load P, the extreme fibre stress "f" in tons per square inch is the moment divided by the modulus of section, *i.e.*—

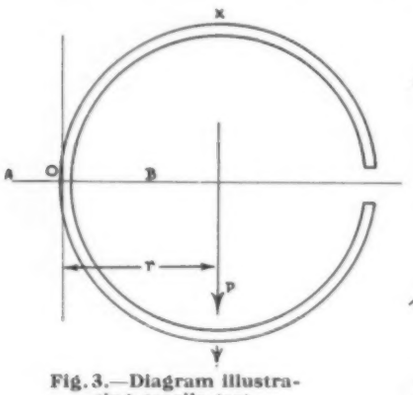

Fig. 3.—Diagram illustrating tensile test.

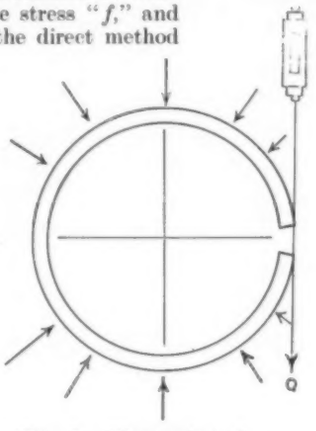

Fig. 5.—Illustrating determination of E_n by tangential closing.

$$f = \frac{M}{Z} = \frac{6\,Pr}{br^2} \text{ pounds per square inch}$$

$$\text{or } \frac{Pr}{374\ bt^2} \quad \text{or } \frac{P\,d}{748\ bt^2} \text{ tons per square inch}$$

where P = pull in pounds
b = width of ring in inches
t = radial thickness in inches
$d = 2r$

At the time this test was put forward the expression and value of modulus of rupture was not so well understood and appreciated as to be regarded as sufficient for an acceptance test, and it was considered advisable to make an attempt to formulate a relationship between moduli of rupture, determined in the above manner, and actual tensile strength values determined on straight tensile test bars of the same material. A large number of comparative tests were made, the tensile bars being cast to $\frac{17}{44}$ in. diameter, and ground to 0·399 in. diameter, this size being chosen to give a structure representative of the structure of the ring castings from which the comparative ring form test-pieces were machined. These comparative tests enabled a relationship between the actual tensile strength and the modulus of rupture to be deduced, the moduli of rupture being found to be approximately 1·6 times the actual tensile strength. The insertion of this empirical constant in the above formula yielded the relationship used in the specification, and was found by further experiment to give comparative results. With the gradual introduction during recent years of the method of expressing transverse test results as moduli of rupture, perhaps it would be preferable to express the results of this "tensile test" on ring-form specimens in similar terms.

It has been pointed out recently (G. Williams, *Automobile Engineer*, August, 1937) that in the application of this test to various newer materials, particularly austenitic cast irons, which possess greater ductility, that an element of inaccuracy arises from taking the bending moment in the formula as P times half the diameter. Owing to the much greater stretch in testing rings of such materials the change in the radius O X, Fig. 1, becomes very substantial as stressing proceeds, becoming less—i.e., O X $= r - x$. If "e" equals the extension in inches of the diameter of the ring in the direction of the application of stress, it can be shown that $2x = \frac{e}{\pi}$. Substituting a correction for this, the formula for the extreme fibre stress becomes:

$$f = \frac{\left(P\,d - t - \frac{e}{\pi}\right)}{748\ b\,t^2} \text{ tons per square inch}$$

This modified formula can be used in connection with these newer materials such as the austenitic cast irons, although the neglect of this correction makes very little difference in the case of ordinary cast irons.

Fig. 4.—Machine for the determination of E_n values.

(*Wellworthy Piston Rings, Ltd.*)

Modulus of Elasticity

The specifications referred to embody an elasticity test which is defined in the following terms. The test ring shall be machined to a radial thickness of not less than $\frac{\text{Diameter (Uncut)}}{34}$, and a piece cut out of the ring so as to leave a free gap of not less than 2·75, and not more than three times the radial thickness. The width (b), the diameter (d) and the radial thickness (t) shall then be determined in inches, and a diametral load (Q) pounds sufficient to close the gap to less than $0{\cdot}25\,t$ shall then be applied. The change in gap (z) shall then be measured and shall be such that E_n, the nominal modulus of elasticity when calculated in not less than $15{\cdot}5 \times 10^6$ lb. sq. sq in.

$$E_n = \frac{5{\cdot}37\left(\frac{d}{t} - 1\right)^3 \times Q}{b \times z}$$

The apparatus required for carrying out tests of this nature on ring-form specimens can be of a very simple character. In the case of the elasticity test for the determination of the E_n value, simple machines of the character illustrated in Fig. 4 are constructed. This particular machine consists of a polished surface plate equipped with a gauge calibrated to read direct in pounds. The ring to be tested is placed between the two diametrically-opposite ball bearings in such a manner that the gap is at right angles to this diameter. By turning the cam-shaped lever, the ring can be closed and the pressure exerted is measured direct on the gauge. The cam-shaped lever is mounted on a fixture capable of sliding in the groove formed in the surface plate, and capable of being locked in a given position to enable different sizes of test rings to be accommodated. The use of ball bearings at the points of application of the pressure is effective in eliminating inconsistencies arising from friction.

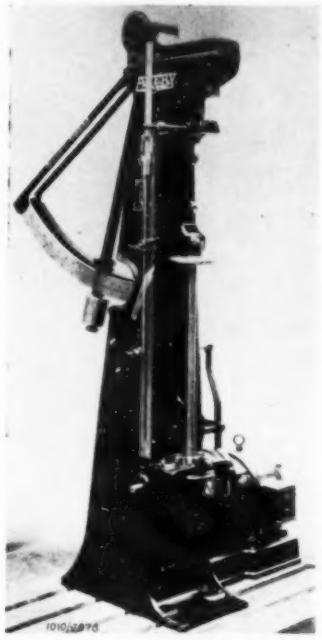

Fig. 6.—Testing machine with recording device for plotting the curve of stress-strain relationship.

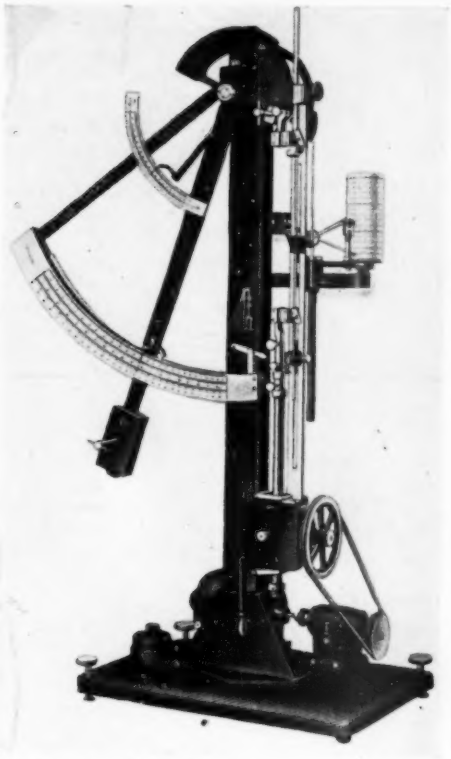

Fig. 7.—A recent testing machine of Continental design, equipped with a motor-driven loading device and pendulum-type counterbalance.

Perhaps the simplest method of all for the determination of this E*n* value is the use of an oiled wire wrapped around the ring. By this means the gapped ring is closed by a pair of tangential forces in the manner shown in the sketch Fig. 5. All the apparatus required in this case is a suitable stand—e.g., a retort stand, from which to support one end of an oiled wire, which, in turn, is wrapped around the ring to be tested, the free end of the wire supporting a scale pan, into which lead shot or weights can be placed. A spring-balance attachment can be interposed in the arrangement to enable a direct reading of the weight required in the scale pan to close the ring gap. The use of this method involves a slight alteration in the relationship for the calculation of the E*n* value as follows, using exactly the same notation as previously—

$$En = \frac{5{\cdot}37 \times 2{\cdot}63 \left(\frac{d}{t} - 1\right)^3 \times Q}{b \times z}$$

For the sake of completeness, it is of value to include the relationship for the calculation of the E*n* value for the conditions of closing the ring by the application of a diametral load at right angles to the gap, the deflection (*e*) being measured as the change in this diameter. The relationship is then

$$En = \frac{2{\cdot}36 \left(\frac{d}{t} - 1\right)^3 \times Q}{b \times e}$$

The derivation of these relationships is somewhat lengthy and can be found in the treatment of curved beams in such textbooks as Unwin, Morley or Prescott, dealing with "Strengths of Materials or Elasticity."

The determination of the breaking strength can be carried out also by similar means of a simple character. In this case the ring is suitably supported at a point at right angles to the gap and weights or lead shot added to the scale pan attached to the test-ring diametrically opposite the support. The weight required to break the ring is the determination of P in the relationship given previously and with the dimensions of the test ring available the breaking strengths can be calculated.

Testing machines are available now for the carrying out of these tests under conditions which are more favourable to the elimination of experimental errors. An illustration of a typical machine for this purpose is given in Fig. 6. This machine, which is of the familiar simple lever type, and its mode of operation will be sufficiently clear from the illustration which incidentally depicts a design equipped with a motor-driven loading device and pendulum-type counterbalance. A recent Continental design of machine for this type of testing embodies the pendulum balance as illustrated in Fig. 7. This type of machine provides the facility for measuring not only increasing, but also decreasing loads, and thus adds to the utility of the machines. The load due to the displacement of the pendulum is indicated on a dial which is provided with a drag indicator, so that the maximum load attained can be read off the dial after the test. A damping device is provided for the control of the return of the pendulum to zero after breaking the test ring. The machine illustrated is equipped with an autographic recording device for the tracing of stress-strain diagrams. The recorder is of the drum type, and permits the observation of the diagram during the test.

A new design of testing machine for this purpose embodying a number of interesting features has been patented and described by G. Williams[1].

For the measurement of the diameter of the test rings a vernier calliper can be used. The most convenient method, however, is to use a circumferential tape. The breadth and radial thickness measurements are made, using a ball-pointed micrometer and the gap measurements by means of a taper gauge. Whilst all these measurements are of a simple character, they are capable of being carried out with a high degree of accuracy. In this connection it is important to draw attention to the need for accuracy in the measurement of the radial thickness, particularly in the determination of the E*n* value, as this dimension is involved to the third power in the calculations.

The use of the ring-form specimen for the determination of the ultimate breaking strength, and the E*n* value (modulus of elasticity) in the manner described, is well established and has been used for the routine testing in addition to acceptance tests for a good number of years. The same method of testing has been extended to the study of the elastic characteristics of cast iron, and there is no doubt that it lends itself admirably to work of this nature.

Stress-Strain Curves

The type of machine illustrated in Fig. 6 is equipped with an autographic recording device for the plotting of the curve of stress-strain relationship, the strain in this case being determined from the change in the diameter of the test ring through the points of support. The actual physical measurement of this change in diameter of the test ring with increasing stress is provided for on various types of machines by the use of a micrometer head attached to the frame of the machine, or by a pointer attached to one of the points of support reading against a scale attached to the frame.

[1] *Automobile Engineer* August, 1937.

As an alternative, the strain can be measured as the change in gap with increase in stress using the taper gauge, and this method is quite satisfactory to operate and is capable of a high degree of accuracy, for the reason that the magnitude of the gap change is generally of a substantial order. The procedure followed in the utilisation of this method is to apply increasing loads to the test ring measuring the gap with each increment in load. Utilising small increments in load it is possible to measure the gaps for all loads up to quite close to the breaking load. The stress-strain or stress-deflection curve is plotted from this data, converting the loads into stress values, utilising the relationship given above and the change or increment in gap as the strain.

Resilience or Toughness Value

The measurement of the included area of the stress-strain curve yields a value proportional to the energy absorbed in breaking the material, and which is frequently spoken of as the resilience value. Largely for the reason that the term "resilience value" has already been appropriated in orthodox mechanics as implying the energy absorbed in stressing the material up to its elastic limit, it is desirable to use some other phrase to express this property. The use of the simple phrase "toughness value" has much to recommend it, and if a new word can be justified, the writer has on a previous occasion proposed the use of a coined word, "Strenergy," for this value of the energy absorbed in breaking the material. This word has the merit of conveying the sense of strength. Whatever word is used to describe the value there is no doubt that it is one of great importance in the study of the strength properties of cast iron, and the value can be determined by the measurement of the area included by the curves using a planimeter.

Permanent Set

For the comparative study of permanent set quite an arbitrary test has so far been adopted. In this case the test ring is subjected to a tensile stress—i.e., opening stress equivalent to 14 tons per square inch. The increment in gap obtained at this stress is measured, after which the load is removed and the permanent increment in gap, if any, measured. This amount expressed as a percentage of the total gap increment is regarded as the permanent set value. There are objections to be raised against this method which has been devised primarily to yield a comparative value of interest in the manufacture of piston rings. In spite of these, it has been found very useful to be able to study the behaviour of this property in different types of cast iron treated in different manners.

Hysteresis

The use of the ring-form specimen lends itself readily to the study of elastic hysteresis. The change in gap can be followed over a complete cycle of stress obtained by opening and closing the ring. The method followed by the author, using the type of machine illustrated in Fig. 6, is to mount the ring in the machine for tensile stressing —i.e., opening the gap. Tensile stressing is applied in gradual increments, measuring the gap opening with each increment up to the pre-determined maximum. The load is then steadily decreased to zero again measuring the change in gap opening with gradual decrement in loading. The ring is then mounted for compression stressing—i.e., closing the gap, and the same procedure followed. The results when plotted yield a loop form of curve, typical of hysteresis curves.

Internal Stress

In the cutting of gaps in test rings it is frequently observed that the gap tends to open or close, or sometimes the free ends of the ring distort out of the horizontal plane of the ring. Movements of the ring of this nature are clearly manifestations of internal stresses existing in the rings, and if the practice is established of cutting the gaps in the test rings in a restrained condition and measuring the gaps in this and the free condition, the amount of gap movement due to the internal stresses is recorded. This procedure is quite easily carried out by clamping the test rings in a vice in such a manner that the free ends of the rings left on cutting the gaps are restrained until the actual gap cut is measured. When this has been done the ring is freed, and the gap measured again. The change in gap is recorded as positive or negative, according to whether it opens or closes in relation to the gap as cut. In the case of hard materials where the gap is cut with an emery wheel, a portable vice or clamp is made to restrain the free ends until the measurement in the restrained condition has been made.

Preparation of Test Specimens and Rings

As indicated, this system of testing was designed in the first instance for the testing of piston rings, which are generally made by machining rings from annular cylinder castings, variously spoken of as a piston-ring pot, drum, shell or quill. Where such castings are available no difficulty is experienced in obtaining suitable test specimens from which to machine test rings.

The common forms of test piece used in general foundry practice are the transverse and tensile test bars, and these are not usually the most suitable form of casting from which to obtain test rings. It is, of course, possible to obtain test rings from them, and the author has frequently obtained rings for investigation purposes from 1·2-in.-diameter bars, rectangular transverse bars, and actual samples of pig iron. For investigation purposes where it is desired to cast test pieces the author adopted the form of test specimen designed originally by the Midland Motor Cylinder Co. Ltd., and utilised by the British Cast Iron Research Association. This test piece, is usually known as the Star test piece. The wings are designed to study the chilling effect, and the rectangular portion attached to the end of the cylindrical portion to study the shrinkage or drawing tendency. These can be dispensed with if desired. The main portion of the Star test bar for the purpose of the preparation of test rings is the cylindrical portion, and the dimensions of the Standard Star bar are very convenient for obtaining a generally suitable-sized ring for test purposes.

The machining of test rings is a simple lathe operation. It is desirable to turn the rings to a fine smooth finish, and precautions should be taken in parting off the rings to prevent the edges of the inside periphery of the test ring being broken into. In obtaining a number of test rings from one specimen it is advisable to scribe a line down the length parallel to the axis of the specimen prior to parting off the rings. This acts as a location, and enables information to be obtained regarding the relative positions of the gaps cut in the various rings, a point which is frequently of some importance, particularly when recording gap movements due to internal stresses.

Test rings can be marked for identification purposes on the inside periphery with ink. Where the test rings are required for further treatment, as for example, heat-treatment, identification marks can be filed on the edges of the rings, preferably at the position which will be close to a free end of the ring when the gap is cut.

The cutting of the gap can usually be done with a hacksaw, the ring being held in a vice for this purpose. Care should be taken to prevent damage to the edges of the rings by the jaws of the vice. After cutting with a hacksaw the free ends of the gap are smoothed off by means of a Swiss file, and it is advisable to scarf the ends to assist in gap measurements by means of the taper gauge. Where the material is too hard to be sawn or filed, the gaps can be cut with a thin emery wheel or slitting wheel. For this purpose the rings are held in a portable vice, and the free ends of the gaps are trimmed off with the emery wheel. This method has been used by the author in studying the properties of cast iron in the hardened and tempered condition.

With the development of improved cutting tools it is possible to turn test rings of this form from very hard materials, using such cutting tools as Stellite or tungsten carbide, and operating with slow speeds and feeds.

Industrial Management and Production Control

By F. L. MEYENBERG

The Essence of Industrial Management

A better understanding of the relative importance of economic, technical and psychological factors in industrial management is necessary to face the problems and perplexities constantly being presented by keener competition, improved quality and more intricate and difficult to manufacturers; wasteful managerial methods must be displaced by more efficient methods, and this article is the first of a series designed to familiarise readers with modern methods for co-ordinating these factors in an effort to develop further improvement in industry. It is primarily an introduction, and deals more with theoretical considerations in order that subsequent articles on practical aspects of management and production control will be more readily understood.

"THE more that I have in practice to do with the problems of industrial leadership, and the longer I am connected with this, the clearer it becomes to me that the mental and moral structure is decisive in an undertaking, and that all mechanistic means must be adjusted accordingly. An industrial concern is an individual being, and only when one has recognised its internal driving forces can one start to form it, to develop the good seeds, and to remove the bad ones.

"If, in doing so, one fails to provide for a 'tolerance' within which those mistakes can occur without great trouble, which must of necessity occur by the nature of the subject, but aims immedately at 100% efficiency one will make serious blunders against the very essentials of the works. The management of a works, therefore, will always remain an art, and one that cannot be replaced by mechanistic auxiliaries. It is certainly very useful to compare the works to a human being—i.e., likened to a body of organic structure, but, of course, the leader must be a born doctor, and not merely a learned 'medical man.' There is in this case the same difference as between medical art and medical science."

These words, translated from a letter of a German friend who has occupied a leading position in industry with outstanding success for many years, may stand for a motto at the beginning of a series of articles which I am permitted to contribute to this journal. They show, indeed, with clearness the spirit in which the work of industrial management should be undertaken. They seem to indicate, however, so it is sometimes said that the task of teaching industrial management should never be made as a leader cannot be trained and educated. This is quite logical. If that were the whole truth, however, it would be better not to write these articles, not to have lectures on industrial administration at our universities, at the technical and commercial schools, and not to discuss the problems of management at meetings of scientific and professional associations and institutes, or even at international congresses.

Does not this conclusion actually mean that one is "pouring out the child with the bath?" Let us consider our comparison more closely for a moment: if industrial management really is an art—and, to a certain extent, I am the last one to disagree with this statement—that can no more lead to the conclusion that the theoretical and educational possibilities of the subject should be abandoned than that mankind would agree to the destruction of conservatoires of music, of academies for painters, sculptors or poets. Yes, the real genius cannot be created at these institutes; this rare quality must be innate in the follower of an art; but he will certainly find his progress assisted by this training even should it do nothing more than provide him with the implements of his trade. How much greater will be the importance of such an education to a man with the mere gift of leadership, whom circumstances of life, family connections, the possession of certain interests, etc., determine from the first that he shall be a future leader of industrial concerns! As practical men, we must think of the conditions of life as they are, not as they ought to be, even if we do not always agree with the trend of actual development.

Thus, the above comparison should never lead us to conclude that it is hopeless to exert any influence on the line of thought of future managers, but, on the other hand, should show the limits of success that can be reached in this branch of science, and thus attribute to a certain modesty so often missing in teachers of industrial administration as well as professional organisers.

Scope of Administrative Training

There is still, however, another aspect from which this teaching and training in industrial management should be considered, and one which is too often neglected. Generally this activity is regarded solely from the point of view of the manager and the future manager, and of the necessity to convey this knowledge to him; but there are naturally a greater number of industrial employees who will never gain any managerial position, and remain the lifelong passive subjects of administration. The opinion is sometimes expressed that these people do not need any administrative knowledge, or even that it would be dangerous to inspire them with it. "These people will only make difficulties if they are trained and understand something of these matters."

I do not believe—and experience has confirmed it again and again during my long industrial life—that this is the right point of view, at least, for the great majority of men employed in industry. I, as well as others, have found that it is much easier to lead an industrial concern where the fundamental principles of administration are well known and appreciated by the subordinates, not only in higher positions, but down to the foremen and junior clerks.

In this connection we have to speak of a phenomenon so unintelligible to outsiders, and so well known in industrial circles—the lack of co-operation among the staff, which sometimes degenerates into secret or even open working against each other. Efforts have been made to find out how much of the work and time of the general manager of an industrial works may be absorbed, on an average, by the settlement of such disputes. I am not impolite enough to declare that a figure of 80%, from American sources, also holds good for other countries, but every expert of industry will agree that one of the weakest points of industrial life is touched upon by these remarks.

Human Aspects

Again, it is sometimes said that these facts are only natural, that they have their origin in human nature, such as it always has been and will remain. It is an easy way out to look at unfavourable circumstances of life in

that way, and a manner which will recoil on those who preach it. Such muddling through leads sooner or later to a rude awakening. Why not think about the causes of these facts a little deeper and, in trying to remove or reduce these reasons, improve the working conditions in industry? To a certain extent, of course, the emotions of jealousy, envy, egotism, fear of losing a living, and other unpleasant traits are the reason for these troubles, and make it difficult to produce any improvement. On the other hand, many of these disputes and quarrels arise from lack of understanding between people, as can so often be observed between employees of the same concern.

My experience leads me to the firm belief that this misunderstanding is mainly caused by the different manner of training which the various groups of industrial employees had undergone. It seems worth while to consider this question in greater detail; possibly nothing will provide a better basis for understanding what industrial management really means.

The Meaning of Industrial Management

It is well known that various industrial concerns may differ in regard to organisation but, generally speaking, there are three main divisions:

1. The Technical side.
2. The Commercial side.
3. The Administrative side.

The technical side is mainly concerned with design and production; when we deal with ferrous or non-ferrous metal works we see that the technical side is moreover concerned with metallurgy; the commercial side is composed of the buying and selling departments; and the administrative side deals with matters of organisation on both sides, the technical as well as the commercial. It is, therefore, only natural that the members of the staff, if they have undergone any special training before entering the undertaking, are either metallurgists, technicians, engineers or merchants. That means that they look at the concern from totally different points of view. We may say—to use, for a fairly complicated affair, some significant if by no means exhaustive expressions—from a more scientific point of view; from a more practical and technical one; and from an economic one. In any case, their work brings them into more or less close touch with the administrative measures, which they naturally consider with quite different feelings.

Whilst they are independent, to a certain extent, at their special work, they must have regard for each other to a greater extent if administration comes into question; but, because they are trained differently, thus learning to think from different points of view, they do not agree upon the question of the importance of any individual administrative measure then under discussion.

This is easily seen when, for example, wage problems are being discussed with members of the different groups of employees. Figures which one needs for judging his own work are unimportant for the other, and vice versa; such figures have to be collected, distributed and allocated in a completely different manner according to the different purposes of the three groups; the original accounts, on which figures of, say, production are fixed, would have a different appearance if developed by the metallurgical, the technical, or the commercial sides. It is here that arise most of the disputes and troubles that we have mentioned above, and that only because the one group has not a right understanding of the requirements of the work of the others.

Is it not obvious that this state of affairs would best be improved by training all concerned from a common point of view, i.e., that of the greatest good of the undertaking in question? In administrative measures scarcely ever is there only one way which could be chosen, but there is only one that will give the best results, although it may appear that requirements cannot be fulfilled which seem to be essential to one or other of the groups concerned. It is this spirit of compromise which has to be aroused if maximum success is to be obtained. Of course, that can also become the case if the work is carried out by blind obedience to the command of the superior, but the question is whether real co-operation can be obtained in that way.

The organisation of a modern industrial concern has inevitably become so complicated that it seems to be dangerous to rely upon the old-fashioned method of command; it should be replaced by conviction, as far as is ever possible, and conviction is easier to establish in the mind of a suitably-trained man, which brings us to the starting-point of our consideration.

Psychological Problems

Looking back over the ground we have covered, we find that there are many psychological problems which we have touched, and naturally enough without being in a position to deal with any of them in detail in this short survey. It would, however, be an intolerable omission if this psychological point of view were not mentioned in an article on the essence of industrial management.

In addition to the material which has to be transformed into goods with the aid of works equipment there are human beings, either within or outside the factory, whose peculiarities must be taken into account carefully; the methods of treatment must vary according to the position occupied by these human beings, either workmen and staff members in the factory, or suppliers and customers outside the works.

Mechanistic Means of Organisation

We have still to deal in rather more detail with one of the sentences in the introductory words of this article: that "all mechanistic means to organisation must be adjusted according to the mental and moral structure of the undertaking." How obvious that is! And yet, how seldom do we find in practice that the task is tackled accordingly! Why that is so we do not know; but in any case, there it is; and we may even observe that those who claim to work in accordance with that sentence are often the worst offenders. These words do not mean that we shall not use those mechanistic means to organisation; we would not be the real children of a technical age if we handled matters so stupidly. On the contrary, we shall use them wherever it is appropriate, relieving human beings from dull, tiring, monotonous office work which can be done better and quicker by a machine, or with the help of time-saving equipment, but we shall choose those auxiliaries "according to the mental and moral forces" which are imminent in the works we are considering. Thus, as each concern is regarded as an individual, there is no "system," no "patent medicine" to be applied in each and every case. The right procedure is to study the works first, to find out the causes behind the matters, then to organise without such mechanical means—i.e., bring all processes into a logical order and a reasonable relation, and finally,—but, in fact, only after this consideration is really finished—to apply such mechanical means as far as they are suitable. They are nothing else than tools of organisation, and should never be taken as being organisation itself.

Conclusion

That may be sufficient to give an idea of the essence of industrial management, but looking back to our considerations, we will now see clearly where are the difficulties. These are not solely scientific, technical or economic matters; they are always interspersed and inter-related with psychological aspects, with regard to the idiosyncracies of the human factor. Very often the employees in the works are not accustomed to this mode of thinking; their outlook has resulted in training in science of metallurgy, of engineering, and of book-keeping by double-entry, and they have to re-learn. This is especially true of those with higher education. They have then to change their mode of thought to a certain extent in regard to psychological facts. For the methods of this science are quite different from those of their previous custom; they may be less exact, sometimes even missing, and then only

"common-sense" can be taken as guide—and should be taken more often than it is. Practical psychology is a science that is still in its infancy, as its best advocates admit openly, and this is proved by the frequently observed fact that many good teachers of psychology are bad psychologists.

And yet this is the common base of an industrial organisation; this intricate formation of co-operating men, materials, plant and money demanding practical psychology for successful management.

It has been necessary in this introduction to deal more with theoretical considerations than is intended for subsequent articles; for no real understanding of facts is possible without knowledge of the basic reasons upon which they rest.

(To be continued.)

The Measurement of Temperature

By E. C. ROLLASON, M.Sc.

The increasing accuracy demanded by modern industrial technique is responsible for the continuous lowering of the permissible degree of tolerance in industrial operations, and since heat-treatment has such an important influence on the properties of metals, the accurate measurement of temperature is increasingly important. In this article the author explains the underlying principles on which the common temperature-measuring instruments are based, and discusses the errors involved.

THE accurate measurement of temperature is becoming increasingly important in almost all branches of industry, but particularly in the control and heat-treatment of metals. There are many errors which may arise in the measurement of temperature, and the object of this article is to outline the construction of the common instruments, but in particular to explain the underlying principles and the errors involved.

Temperature Scale

The absolute fundamental temperature scale is based on the Second Law of thermodynamics and a "perfect gas," for which

pressure X volume = constant Y temperature (K).

The unit degree on the scale is defined arbitrarily as one-hundredth of the temperature interval between the freezing point (273° abs.) and the boiling point (373° abs.) of pure water. Although no perfect gas is available, hydrogen or nitrogen can be used in an instrument known as a constant volume gas thermometer, and slight corrections made for the lack of perfection. The zero point is chosen, as that temperature where the gas volume becomes zero, the lowest conceivable temperature corresponding to − 273° on the centigrade scale, which has its zero at the freezing point of water.

The gas thermometer is a difficult instrument to use, and it must be regarded as a primary instrument which has been used to measure the freezing points of a number of pure metals and substances which can be employed to calibrate secondary pyrometers of greater flexibility.

Secondary Pyrometers

A number of instruments depending on various physical properties are mentioned below :—

(*a*) *Thermometers.*—Depending on the relative expansion of mercury in glass or in steel, in common use up to 300° C., and the range may be extended to 500° by filling the stem with nitrogen under pressure.

(*b*) The heat content of hot bodies—e.g., *Siemen's Calorimetric Pyrometer.*

(*c*) *Fusion.*—Triangular pyramids, moulded from various mixtures of kaolin, lime, feldspar, magnesia, quartz, iron oxide, and boric acid, are used to indicate temperatures in steps between 600° and 2,000° C. Each cone has a definite composition, and fuses at a certain temperature, indicated by the bending and final collapse. Reducing atmospheres affect the end point. Such cones are named "Seger," "Orton," and "Sentinal."

(*d*) *Colour Extinction* (e.g., Pyroversum 600°—1,200° C.) A graduated colour filter is superimposed until it neutralises the colour from the hot body. The objection to colour pyrometers is that they depend on the sensitivity of the human eye to colour, and this varies not only with different observers, but also with the same operator under different physiological conditions.

(*e*) *Electrical Resistance Pyrometer.*—This depends on the variation of electrical resistance of a platinum wire with temperature. In the range below 600° C. it gives the greatest accuracy of all the secondary instruments, but it is delicate and bulky, and for these reasons it is not used extensively in industrial installations.

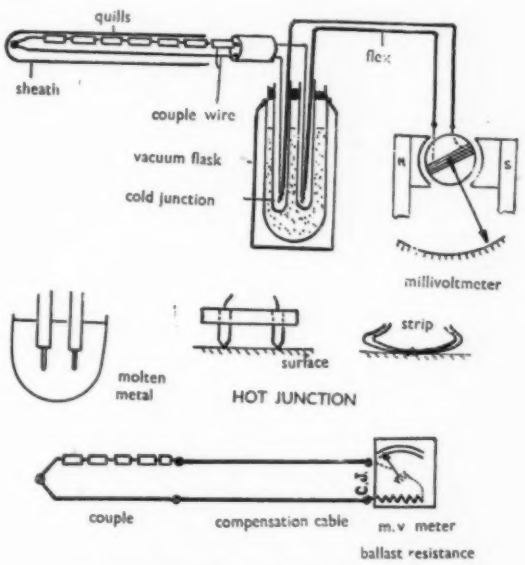

Fig. 1.—Thermo-electric pyrometer.

(*f*) *Thermo-electric Pyrometer.*—This is now the most extensively used instrument, and it will be described in detail. The basal principle of it is that when two dissimilar wires are joined to form a complete electric circuit and the two junctions maintained at different temperatures, an electro-motive force (E.M.F.) is set up, due to the algebraic sum of—

(i) An E.M.F. developed between two different metals placed in contact—i.e., *Peltier effect.*

(ii) An E.M.F. is developed between the ends of a homogeneous wire when one end is heated—i.e., *Thompson effect.*

The magnitude of the E.M.F., therefore, depends on the temperature difference of the junctions and the metals used. If one junction is held at a uniform temperatu e (cold junction) then the E.M.F. developed can be used to determine the temperature of the other junction (hot junction). This arrangement of conductors is called a thermocouple. The complete pyrometer consists of the following parts :—

(*a*) Two dissimilar conductors in wire or rod form.

(*b*) Electrical insulation of the wires.
(*c*) Sheaths for protecting the wires from injurious gases.
(*d*) Provision for controlling the temperature of the cold junction.
(*e*) Instrument for measuring E.M.F.

Types of Thermocouples

The following properties are desirable in a good thermocouple :—
(*a*) Uniform and reproducible change of E.M.F. with temperature.
(*b*) High E.M.F. and high melting point.
(*c*) Good resistance to corrosion and oxidation at elevated temperatures.

Data for common couples are given in the following table, and the construction is shown in Fig. 1.

Couple Wires.	Upper Limit, ° C.	Millivolts per 100° C. Approx.
Copper—constantan (Cu 60, Ni 40)	300	4·3
Iron—constantan	700	—
Chromel—Alumel (Ni 90, Cr 10—Ni 98, Al 2)	1,100	4·1
Platinum—platinum + 10% rhodium ...	1,200	0·96
Tungsten—molybdenum	1,700	0·8
Carbon tube—silicon carbide rod	1,800	30

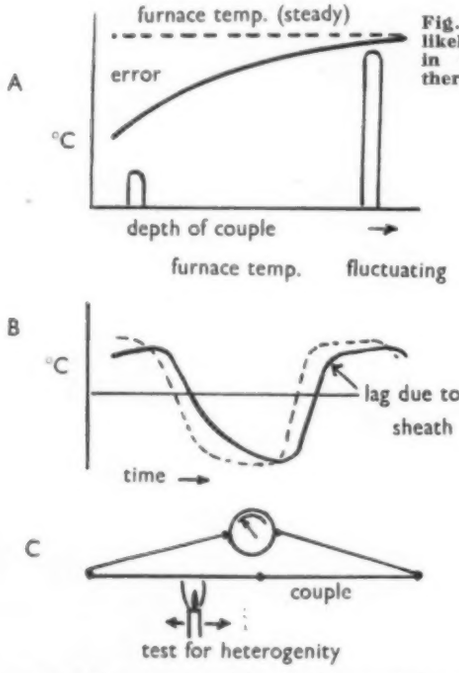

Fig. 2. — Errors likely to arise in the use of thermocouples.

The E.M.F. developed by the base metal couples is four times that of the platinum couple, and owing to low costs thick wires can be used, resulting in lower resistance of the external circuit and longer life of the couple. Consequently a simple and robust millivoltmeter can be used. Against these advantages, however, the base metals cannot be made as homogeneous, nor is their life as great at the higher temperatures as the platinum group. Thick wires allow heat to be readily conducted away from the hot junction. Nickel and platinum alloys are ruined by sulphurous gases, but the attack can be largely prevented by inserting the end of the couple sheath in a jacket containing lime which absorbs sulphur. The E.M.F. of a platinum couple is also effected by reducing gases in the presence of any metal, carbon, or refractory silicates, due to the absorption of carbon silicon or metal vapours.

The tungsten-molybdenum couple, however, must be protected by a reducing atmosphere of dry hydrogen or hydrogen-nitrogen mixture. This couple should not be used below 1,200° C. owing to an inversion in its E.M.F.—temperature curve.

Hot Junction

The two dissimilar wires have to be electricaly connected to form the hot junction, and this can be done in several ways. For the constantan couples the ends on the wires can be cleaned, twisted together and silver soldered (Cu 48, Ag 48, Zn 4) using borax as a flux. The chromel-alumel couple can be welded in an electric arc and the platinum wires in an oxy-hydrogen flame. To get a couple sensitive to changes in temperature there should be no unnecessary mass of metal in the hot junction. The composition of the actual hot junction does not matter so long as the whole of it is at the same temperature. In certain immersion or surface instruments it is found unnecessary to weld the wires, the ends being left bare and contact made by the molten metal or the metal surface itself.

Insulation and Protection of Thermo-element

Either one or both wires are electrically insulated by silica or fire-clay capillary tubing, and the whole is inserted in a sheath consisting of fused silica (1,250° C.) glazed porcelain or alundun (Pythagorus) up to 1,700° C.

This sheath, closed at one end, should have high conductivity, low permeability to gases, and ability to withstand changes in temperature and also mechanical shocks. In industrial pyrometers, this sheath is also provided with mechanical protection by an outer tube of carborundum nichrome or calorised tube.

Cold Junction

For laboratory use, it is convenient to connect the couple wires to copper flex, and each junction is enclosed by a glass tube closed at the end and fitted into a vacuum flash filled with melting ice or oil (Fig. 1). This method of controlling the cold-junction temperature is not suitable for many industrial installations. It is frequently easier to transfer the cold junction from its proximity to the hot junction to a place where the surrounding temperature is lower and steadier. The thermocouple is joined, therefore, to what are called compensating leads, which are wires thermo-electrically interchangeable with the couple wires. Base-metal couples are extended by wires of practically the same material as those employed in the couple itself, but in the form of stranded wires for flexibility. For platinum couples are used inexpensive wires of copper and nickel-copper alloy, which give the same E.M.F. as the couple over ordinary ranges of temperature.

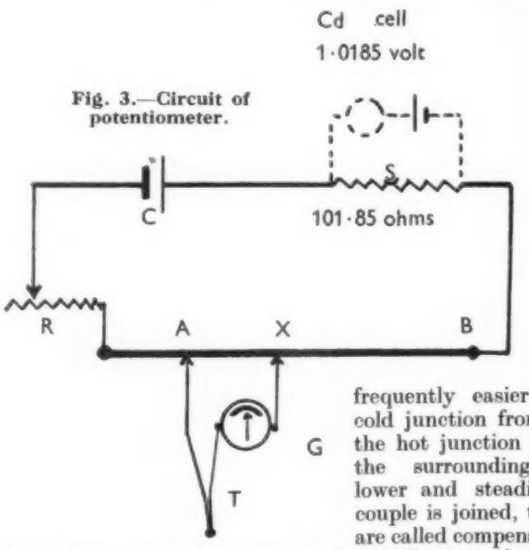

Fig. 3.—Circuit of potentiometer.

In most industrial installations the compensating cables extend to the terminals on the indicator, but it must be remembered that variation in temperature at this point still needs correction to be applied. With a millivoltmeter the common method is to set the points to the actual cold junction temperature, except in instruments in which this is done automatically, by a bi-metal spring. Since few couples yield an E.M.F. which is directly proportional to temperature, it is *not possible to add the variation in cold junction temperature to the observed temperature.* The E.M.F. corresponding to this variation must be added to the observed E.M.F.

Measuring Instruments

The E.M.F. is measured by either a millivoltmeter or a potentiometer, and both methods can be adapted for recording.

Millivoltmeter.—This consists essentially of a moving coil mounted between the poles of a permanent magnet. The coil can be suspended by metal fibres or more commonly supported by one or two jewelled pivots, the torque taken by coiled springs, and the movement indicated by a pointer.

The instrument should have a *high electrical resistance* relative to the external circuit, and it should not vary greatly with temperature. While a resistance of 40 ohms may be sufficient for a base metal couple, one of 500 ohms is usually desirable for a platinum couple. The reason for this is that the instrument uses current and measures an E.M.F. which depends on the total resistance of the circuit. Any variation in the external resistance will affect the reading, and this may arise, due to variation of the depth of insertion of the couple in the furnace since its resistance depends on temperature (Fig. 2a). The high-resistance instrument is usually made by adding a ballast-resistance having a low temperature coefficient, which in turn necessitates more copper wire on the coil or a more sensitive movement or a stronger magnet. Such an instrument is of course more delicate than a low-resistance instrument used for the same purpose.

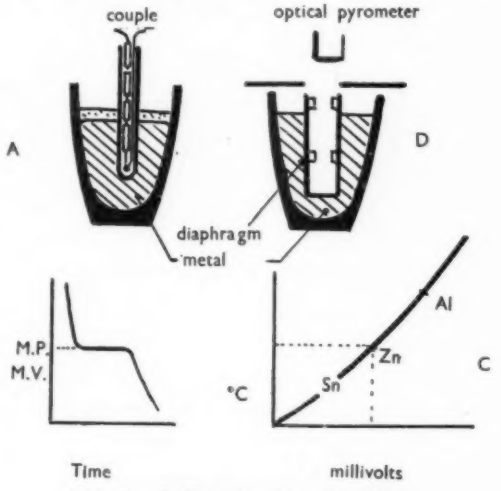

Fig. 4.—Calibration of pyrometers.

The indicator should be *dead-beat*—i.e., the pointer should not oscillate many times before coming to rest. A heavy coil and pointer will tend to prevent quick damping. For consistency and accuracy, the magnetic flux between the poles of the magnet must be constant, and this will not be so if the instrument is mounted near cables carrying heavy currents or on steel stanchions, unless it is *magnetically shielded* by a soft iron cage or box. Finally, the terminals should be shorted with heavy copper wire to damp the movement when the millivoltmeter is moved.

Potentiometer.—These afford the most accurate method of measuring the E.M.F. of a thermocouple, which is opposed by an equal E.M.F. to produce a balance. No current is used, and consequently the usual changes in the external circuit have no effect on the readings.

Essentially, a potentiometer is a number of resistance coils (A–B, Fig. 3) through which a steady current is passed from accumulator C. This current is kept constant by occasionally adjusting it by means of the rheostat R, so that the fall in potential through a fixed resistance S balances the E.M.F. of a standard cadmium cell *c d* (1·0185 volts at 15° C.). Then since in a simple circuit the fall in potential is proportional to the resistance, an unknown E.M.F. can be measured by balancing it against the drop over the appropriate known resistance. One end of the couple is connected to A and the other end through a galvanometer to a suitable tap X. The galvanometer indicates when a balance point is reached, and this arrangement is known as the "*null*" method. In the *defection* potentiometer (Carpenter-Stansfield) deflections of the galvanometer are also used to give vernier readings of E.M.F. but to do this it is necessary to have two equal resistances (A B), so that the total resistance in the couple circuit is always constant.

Errors.—Some of the errors which arise in the use of thermocouples are illustrated in Fig. 2. With a steady furnace temperature the reading will be affected by the *conduction of heat* along the sheath and wires, and this will vary with the material of the sheath, thickness of the wires, and depth of immersion of the couple in the furnace. There is also a very large time *lag*, with heavily protected couples, which introduces errors when the temperature is fluctuating. Other errors arise, due to parasitic E.M.F. arising from (1) heterogeneity in the couple wires which are in a temperature gradient; (2) electrical leakages into the couple circuit. Heterogeneity due to composition or cold work can be tested as shown in Fig. 2 by connecting the two ends to a sensitive galvanometer and passing a small flame along the wires. No deflection should be produced except at the junction, unless the couple is contaminated.

Calibration.—Calibration of a thermocouple can be made by comparison with a standard couple of known accuracy or by measuring the E.M.F. produced at the boiling or freezing point of pure substances, such as boiling point of water, freezing point of tin, lead, zinc, aluminium, sodium chloride and copper (under charcoal).

The metal is melted in a small foundry crucible under charcoal, and the thermocouple, with sheath, is inserted in it, so that the hot junction is surrounded with molten metal (Fig. 4A). While the metal cools readings of the millivoltmeter are taken every 15 seconds. When the metal begins to solidify the pointer remains stationary, and this reading corresponds to the fixed freezing temperature of the metal (at a given cold junction temperature).

The observed readings for a number of metals can be plotted against temperature to form a calibration curve for the couple (see Fig. 4c).

(*To be continued.*)

High-duty Cast-iron Specifications

IN view of the progress in the production of high-duty iron castings, it is not surprising that a new specification has now been issued by the British Standards Institute for high-duty cast irons calling for tensile strengths up to 18 and 22 tons per sq. in. Although this specification displaces a specification in which the minimum tensile strength called for was 11 tons per sq. in., and which had been issued about 10 years, it is only fair to say that high-duty iron castings capable of meeting all the requirements of the new specification have been produced in this country for many years. Apart from improvements in melting and in foundry methods and processes, the development and increased production of alloyed castings has contributed largely to the advancement of cast iron in its application to high-duty service in modern engineering.

Canada's Cobalt Production

MOST of the cobalt produced in Canada has come from the silver-cobalt mining camps at Cobalt, Gowganda, and South Lorrain in northern Ontario. The greater part of it is obtained as a by-product of silver mining, consequently production varies more or less in accordance with activity in the latter. Some ore is, however, mined chiefly or solely for its cobalt content. The only plant in Canada treating ores for the recovery of cobalt is that of the Deloro Smelting and Refining Co., Ltd., at Deloro, Ontario, which produces cobalt metal, oxides, and salts chiefly for the British market. A considerable portion of the ore produced in Canada is sold for treatment abroad.

Practical Application of Hot-Face Insulating Bricks

By J. W. JACKSON

The application of "hot-face" insulation in furnaces, stoves, kilns, etc., has many advantages in comparison with the use of insulating backing bricks; it reduces the heating and cooling time, thinner walls are necessary, which reduce space and there is a saving in fuel or electricity. In this article the author discusses some of the factors of heat insulation which will assist in removing uncertainty that apparently exists in the choice of bricks for heat-insulation purposes.

THE purpose of this article is to explain and answer some of the many questions which are asked from time to time about heat insulation. Although the primary advantages to be gained are almost universally appreciated very considerable uncertainty exists in connection with the application and choice of bricks for heat-insulating purposes. This applies even more to that branch of insulation known as "hot-face" insulation, or the use of insulating bricks for the actual lining of furnaces, stoves, and kilns, etc. Broadly speaking, the advantage of this method over the use of insulating backing bricks is that the heating and cooling of a furnace so built becomes a shorter process. This is due to the "smaller heat capacity" of the material used to line the furnace. The extent to which this acceleration of heating and cooling can be effected is astonishingly high—for example, the heating period of an annealing furnace may be reduced by considerably more than 50%. But this is scarcely more astonishing than the fact that in some furnaces of this type as much as 60% of the heat generated may be employed in heating up the furnace walls and maintaining temperature against the effect of heat conduction through the walls and subsequent dissipation into the atmosphere. An added benefit is the lighter structure which is made possible by the use of this type of insulating lining.

Insulating Firebricks

It is commonly supposed that an insulating firebrick—that is, a fire-clay brick made porous artificially—is a very frail and delicate object which can readily be picked to pieces with the hands. This may be true in certain cases, but there is quite a large range from which to choose a good tough brick. The general rules applicable in the choice of ordinary firebrick should apply in the case of insulating bricks. That is to say, they should be hard burnt, of an even texture—this is particularly important, and they should be true to shape and size. This latter feature brings us to the question of bricks which are cut to shape after firing. It should be understood that this practice is in most cases carried out as a necessary expedient rather than as a refinement.

The difficulties in making insulating bricks with porosities ranging from 60% to 85% are very considerable, especially if the finished product is to be true to shape and size. The methods employed—either the addition of combustible matter which is subsequently burnt out to leave pores, or the gasification method—tend to produce mis-shapen masses due to excessive shrinkage or warping. Most manufacturers would rather spare themselves the very considerable expense of machining to shape, but are prevented by the circumstances mentioned above. Of course, accuracy of shape and size is important because it allows gas-tight joints to be made, and this is a very necessary feature of an insulating wall. Weighing up the pros and cons, however, it is very much better to have a good square brick upon which the original skin of burning remains than one which has been machined to size at the expense of its outer "skin."

The foregoing remarks bring us to another aspect of high-temperature insulating brick. It is important to note that this type of brick may not necessarily be suitable as a hot-face insulator. That is to say, it may not be tough enough or sufficiently resistant to conditions which it may be called upon to face as a furnace lining material. This, of course, does not mean that this particular brick is useless. It may be extremely efficient as a high-temperature backing brick to a thin refractory lining. The term "refractory" is here used in its true sense—i.e., not mere ability to withstand high temperatures, but rather to resist adverse conditions, such as fuel ash attack, erosion, etc., at elevated temperatures. Indeed, there are many cases where hot-face insulation is out of the question. For example, it would be impracticable in close proximity to a high-temperature pulverized fuel burner. The hot-face insulating brick is, however, an improvement on the high-temperature insulator.

Few manufacturers make any distinction in this direction, and the choice therefore lies at the discretion of the consumer. He must ask himself, "Is this or that brick sufficiently tough or resistant to the conditions to which it will be subjected?" In certain cases, in the absence of previous knowledge or precedent, it is wise to contrive some test which will reproduce the conditions expected. There are insulating bricks available now which have successfully withstood severe abrasion, spalling, and slag attack tests. The use of such bricks can, of course, be undertaken with more confidence than would be the case if nothing were known of their characteristics. Hot-face insulation may, in certain cases, give the very opposite result to that which is desired. In certain plant, the object is to have a structure with a large heat capacity, so that dense bricks, having regard to other requirements, such as resistance to spalling, should be used. A typical example is the open-hearth furnace regenerator chequers. Hot blast stoves constitute another example. In these two instances, of course, an insulating backing is a very necessary feature.

Hot-face Insulation

Hot-face insulation will be most beneficial when used in intermittent furnaces and stoves. In such cases, advantage is taken of their low heat capacity, which saves time during heating and cooling, as explained at the beginning of this article. Another very striking example of the advantages gained by substituting insulating firebricks for ordinary firebricks is in producer gas mains. The effect of this is to increase the surface temperature within the main. This prevents the condensation of the less volatile fractions of the gas, thereby increasing its calorific value when delivered to the furnace. In addition, since less tarry matter is deposited, the necessity for burning out becomes less frequent. Of course, in choosing a brick for such a purpose it should be ascertained that it is capable of withstanding the temperature attained during "burning out."

A good lining of insulating bricks exerts a very strong influence on the outer structure of a furnace or kiln. Since such a brick has a low heat capacity its surface temperature rises more rapidly than would that of an ordinary firebrick. The higher the surface temperature, the more complete is the heat reflection from walls, and the more even therefore is temperature distribution. This, in turn, means that stresses due to thermal expansion are more evenly dis-

tributed, so that cracking of the outer walls is minimised.

As with other types of brick, allowance must be made, in the form of expansion joints, for thermal expansion of the insulating brick themselves. Provided a strong brick is chosen, there is no reason why furnace or kiln arches should not be sprung from the insulating lining. In fact, if this is done a far more gas-tight structure can be made because the crown and walls may rise and expand integrally.

Heat Losses in Furnace Foundations

It is not commonly appreciated how great are heat losses into the foundations of furnaces or kilns. During the heating period the foundations absorb heat to a surprising extent. Anyone who has had occasion to dig out the foundations of a kiln will have been surprised at the depth to which vitrification and drying out of the soil has taken place. This represents an enormous reservoir of heat, which during the cooling period is fed back into the kiln or furnace, thus prolonging the process. By placing the unit upon a raft of insulating bricks it is isolated and therefore any heat generated is confined where it is intended to be used. The object in insulating any structure should be to place the insulating bricks as near as possible to the hot face, whether of combustion chamber or flue.

Spalling Tests

On account of their properties of resisting the passage of heat, insulating bricks tend to spall more readily than ordinary firebricks. The usual spalling tests which are applied to ordinary firebricks are too crude in connection with insulating firebricks; indeed they are meaningless except perhaps for purposes of comparing one insulating brick with another. "Usual" tests mentioned above refers to the method of plunging a brick into a furnace at an elevated temperature. Occasionally this test is operated with the heating referred to above, and a cooling cycle intensificd by a blast of cold air. Further, when subjected to such a test as that described, it should be borne in mind that all six sides of the brick are under test. Far more instructive results are obtained by building several bricks into a panel so that only one side of each brick encounters thermal shock. Except in the immediate vicinity of jambs or wickets, the likelihood of severe and sudden extremes of temperature is not great. The expansion of any cold air entering the unit would render the possibility of a blast of cold air on the brickwork very remote. In those places where cold air must of necessity impinge on the bricks suitable precautions can be taken. In these times, when specialisation of refractories is an established fact, such a step is natural.

A number of years ago firebricks were used throughout the various zones of melting furnaces, cement kilns, etc. The introduction of special refractories—magnesite, chromite, carborundum, dolomite, and high aluminous or bauxitic bricks—has rendered the design of such plant a matter of individual consideration, and the same process must inevitably take place in connection with insulating bricks. Manufacturers of such bricks will be only too pleased to advise on the most economical and suitable method of application.

Objections to Heat Insulation Considered

Before turning to the practical economics of the subject it may be worth while to mention a few of the objections which are frequently raised against heat insulation. It is sometimes said—and this may sound fantastic when considered seriously—that insulation will raise the temperature of the plant above that at which it is supposed to be worked. The answer to this is, of course, that fuel should be reduced. It is perfectly true that, given the same fuel consumption, insulation will increase temperature.

Another objection is that an insulated furnace would cool more slowly than one not insulated. Clearly, if the heat capacity of the bricks is smaller, there is less heat to dissipate during cooling, and this therefore becomes a quicker process. It might, however, be true to say that a furnace having a very thick firebrick lining and an insulating backing would cool more slowly. This, in fact, constitutes one of the salient points in favour of hot-face insulation, and represents progress made in industrial application of heat.

Application of Insulating Bricks

Although this has been mentioned before, it would perhaps be as well to consider further the best method of applying insulation, taking into account particular conditions. For example, in places where there exist conditions calculated to be dangerous to ordinary firebricks, insulation, or rather hot-face insulation, should not be used. In such positions the thinnest possible refractory lining, compatible with service required and mechanical strength, should over-lie the insulating bricks. This applies also to furnace-charging ports and fire-holes, etc. If such points as these are carefully observed, insulation will certainly return, with interest, the capital outlay involved in its installation.

One frequently comes across cases where insulation has been considered and rejected, due to fear of collapse or failure. Bogie furnaces, for example, are often thought to be unsuitable for hot-face insulation owing to the fact that enormous drops in temperature are occasioned by withdrawing the charge. In a furnace of this type, the doors must necessarily be very large, and when opened it is tantamount to removing practically the whole of one side of the furnace. Most insulating bricks have a distinct danger temperature zone. That is to say, many insulating bricks can be cooled extremely rapidly, say, from 1,000° C. to 600° C. without danger of spalling, whilst for another brick this might be an extremely critical period. If these features are borne in mind when ordering bricks, the likelihood of damage in this direction will be no more than in the case of ordinary firebricks.

An examination of the thermal expansion curve of a number of bricks will soon show which of them would be most suitable for the purpose in mind; a suitable brick having been chosen, it should be an easy matter to arrange that the furnace door is lowered as soon as possible after withdrawing a charge, so that too sharp a drop in temperature will be avoided. Elementary precautions of this kind render the use of insulating bricks possible and, indeed, very economical in a great many positions in industrial practice.

Many older types of reheating furnaces cannot economically be insulated by means of backing bricks of the low-temperature type. If such a plan is carried out without careful calculation, it will be found that the refractory lining is not sufficiently thick to protect the insulating bricks from excessive temperature. This very often means that extra thickness would have to be added to the lining, thereby reducing the area of the hearth. Not only is such a plan undesirable for the reason mentioned above, but also it is extremely inefficient because heat is being conserved, not within the furnace itself, but within the furnace fabric. A lining of hot-face insulating bricks will allow the size of hearth to be increased to even greater dimensions than when using ordinary firebrick, and, in addition, it is considerably more efficient. Many furnaces have remained uninsulated owing to lack of the hearth space which a low temperature insulating brick would require. As shown above, hot-face insulation solves both these problems with a considerable balance of efficiency in hand.

The saving in fuel costs brought about by hot-face insulation will to a large extent depend on the design and type of the furnace or kiln. It is relatively easy to calculate the saving in heat—i.e., B.Th.Us.—but to convert this into percentage saving in fuel presents a different problem. The following example gives a basis for such computations.

Calculating Heat Saving

A rectangular down-draught kiln, completely insulated with 4½ in. of hot-face insulation, inside walls backed with

18 in. of red bricks, 9 in. hot-face insulation crown, and standing upon a raft of 4½ in. of semi-insulating firebricks was found to take 14·6% less fuel than a similar kiln of the same dimensions, but completely uninsulated. From calculations it was determined that the heat losses on the insulated kiln taken on an average for the whole kiln fabric were 374 B.Th.Us. per square foot per hour. Calculations in the case of the uninsulated kiln showed that the heat losses would be in the neighbourhood of 670 B.Th.Us. per square foot per hour, so that the saving in heat on the insulated kiln would be 44%. Thus, in the case of these two kilns 44% saving heat represented a fuel saving of 14·6%. The relationship between these two figures will, of course, vary in different kilns, furnaces, or stoves, depending on their efficiency and such features as regeneration and recuperation. With further reference to the examples given above, it should be noted that not only is there a considerable decrease in fuel consumption, but the uninsulated wall is 4½ in. thicker than the one in the insulated kiln. This means that 4½ in. of high-temperature insulating brick, together with 4½ in. of red brick, have replaced 9 in. of firebrick, so that even the capital outlay is not so much greater than would at first appear.

Special Manufacturing Technique

The apparently high price of insulating firebricks may have led users to the conclusion that hot-face insulation is simply a new departure in industrial practice which is being exploited whilst the novelty lasts. Unfortunately, there is very little chance of any considerable reduction in the present market price of bricks of this kind. This is for the very good reason that cost of production is extremely high. Investigation will reveal the fact that very few manufacturers confine their activities to the production of high-temperature insulating bricks. Many firms have, at one time or another, undertaken the manufacture of porous firebricks as a secondary product to ordinary firebricks. The addition of such cheap or apparently cheap combustibles as sawdust to the clay batch appeared to be a very simple and inexpensive method of producing an insulating brick. Unfortunately, very special technique is required in other phases of manufacture—particularly in burning.

The difficulty lies in producing the bricks true to shape and size. There are two alternatives. Either special methods and care are adopted to bring the brick true to shape after burning or any inaccuracies are remedied subsequent to burning by grinding or trimming. The expense involved in such individual attention to each brick as the latter method implies is obvious, although it is true that some saving can be made by disposing of the material which is ground off each brick, as an aggregate, or grog for refractory insulating concrete.

The rate of production of insulating firebricks, on account of the methods employed, is lower than the rate at which ordinary firebricks can be produced. The extra time involved may occur in the initial or final stage of manufacture according to the methods employed. Whatever the reason may be, lower production means higher costs, so that apart from the cost of materials manufacturing costs are also higher.

As regards the actual market prices of insulating bricks, it is clearly impossible to make any comparison with the price of ordinary fire-clay bricks. The hot-face insulator, besides conserving heat and economising time, is performing the function of an ordinary firebrick as a furnace lining material.

At the beginning of these observations, reference was made to the advantages which accompany the use of hot-face insulation. These are summarised as follows :—

1. Saving in fuel.
2. Saving in time—cooling and heating.
3. Saving in space, owing to thinner walls.
4. Due to the thinner walls mentioned in 3, lighter construction is required and less refractory materials are necessary.
5. Reduction of air infiltration ; the even distribution of temperature mentioned in the course of these remarks reduces the cracks in outer structure, making a more gas-tight structure.
6. Uniformity of temperature increases quality of furnace charge or kiln-ware to a very marked extent.
7. Even distribution of temperature plays a particularly important part in heat-treatment of all kinds of goods and ware. Working temperatures can be reduced to very much finer limits than is possible with a firebrick lined furnace.

Water Tube Boilers

FOR the operation of smaller sizes of water tube boiler, such as is used in the iron and steel industries, as well as collieries, for example, hand or sprinkler stoker firing, with coal or coke breeze, can be carried out in an efficient and convenient manner either alone or in conjunction with gas-firing, by means of the "Turbine" forced-draught furnace, especially when fan operated. By this means a high rate of fuel consumption per square foot of grate area, and therefore of evaporation, can be obtained, which applies even when burning coke breeze, high in ash or moisture content, or both together.

It may be remembered, the forced-draught furnace, operated either by steam jets or a fan with trunking as required, is a production of the Turbine Furnace Co., Ltd., and consists of a series of large cast-iron trough firebars, placed longitudinally side by side to form a grate of any desired width and up to, say, 6 ft. long, in which are fitted loosely a considerable number of small transverse bars.

Any desired degree of draught can be given merely by adjusting a valve or switch, and the temperature of the fires is extremely high, whilst secondary air can be added at the back of the grate, say, by means of a damper operated by a lever from the front of the boiler, using a small proportion of the forced draught for the purpose. For high ash content fuel and rapid cleaning of the fires an extension cleaning-out grate is also available. In general, fan-forced draught is better for water tube boiler operation, because, as against steam jets, a continuous air blast of higher pressure can be obtained.

The power consumption also is less, being not over the equivalent of 0·5% of the total evaporation, whereas steam jets are, say, 2·5—3·0%, about the same as induced draught (obtained by a fan). Other advantages are noiseless operation, and no addition of steam to the furnace in the case of high moisture content fuels. Many coals, however, with low moisture content give a more granular and easily removed ash when moisture is present, an inherent advantage, amongst others, of steam jets, but in this connection a small amount of steam can be added to the air blast from the fan. Many "Turbine" furnace installations are operating with water tube boilers burning coal and other types of fuel. Thus, in one case wood chips are the fuel used, the grate being contained in a "Dutch oven" type of combustion chamber in front of the main boiler setting, with a feed hopper at the top.

Another interesting installation is a battery of 14 hand-fired water tube boilers at a colliery in South Wales, each of which have a combustion chamber 6 ft. wide between the side walls. The forced draught is arranged so that one fan with direct-coupled electric motor and the necessary main trunking and branch connections to below the grates supplies six boilers. For the other eight boilers, two separate sets of fans and trunking are operated. Extremely low-grade fuel also is used, chiefly small coal (fines) and slurry from coal washers. At another colliery in South Wales six water tube boilers equipped with the fan-forced draught furnaces are burning coal screenings, the fan being driven by a steam engine. In a number of cases also both water tube and "Lancashire" boilers are operated side by side, whilst another important field for the furnace is the marine water tube boiler.

The Trend of Chemical Engineering

The importance of chemical engineering in the world's progress is increasingly manifest, and the need for the efficient application of technical and scientific knowledge in this complex field was never greater than to-day. In view of the importance of this industry, there is special interest in the survey, under the above heading, by Dr. W. M. Cumming and Mr. F. Rumford, presented at the recent autumn meeting of the Society of Chemical Industry, salient features of which are given in this article.

THE efficient application of technical and scientific knowledge in the chemical engineering industry is of vital importance. With conditions of temperature and pressure becoming steadily more exacting in many forms of chemical plant, and the demand for higher economic efficiency being steadily pressed, there is a special need for study in this field which this country cannot afford to overlook. Chemical engineering has become such a highly complex field that its recognition as a separate department of applied science in our university centres is long overdue.

The trend of development in materials for chemical engineering is noteworthy in that well-established materials of construction retain, by reason of improved technique in manufacture, an important place. Manufacturers continue to develop metals and alloys possessing remarkable mechanical and corrosion-resisting properties, but as yet there is no clear idea of the causes of corrosion, the effects of which still constitute a major problem.

Iron and Steel

Cast iron is still the most important material of construction of chemical plant; its position has been maintained largely as a result of the great improvement which has taken place in foundry practice within recent years. The production of special cast irons, in which varying amounts of other metals such as Ni, Cr, Mn, Cu, Al, Mo are added, provide the chemical engineer with materials which offer considerably increased resistance to chemical reagents. Such alloys as Ni-resist (14% Ni, 6% Cu, 2% Cr) and Nicrosilal (18% Ni, 4%—6% Si) have, in addition to good chemical resistance, good wearing and heat-resistance characteristics, the latter showing no appreciable change up to about 1,000° C.

The development of chromium steels in America has run parallel with that of the 18·8 chromium-nickel steels in this country, and it is interesting to note that in the pressure oxidation of ammonia to nitric acid, chromium steels are employed for the most important units of the plant in the U.S.A. The most important industrial application of the 18·8 steel is in the manufacture of synthetic nitric acid from ammonia. Much pioneering work has now been done, and by the addition of small percentages of other metals, e.g., titanium, molybdenum, and tungsten, the steel has been made more resistant to specific media (e.g., acetic acid, sulphuric acid); it became almost immune to intercrystalline corrosion, and permitted of welding without the necessity of subsequent heat-treatment.

One outstanding development in the use of these special steels is for high-temperature—high-pressure reactions, resulting from an appreciation of the importance of creep at elevated temperatures. For example, the addition of 0·35% Mo to ordinary steel increases its creep strength at 450°—550° C. by 100%, while for high pressure above 525° C. the austenitic steels prove satisfactory on account of their excellent creep properties. As in the case of the acid-resisting steels, the addition of small percentages of other metals confers additional advantages where corrosive conditions are present. Especially is this the case in their resistance to hydrogen attack, resulting in decarburisation and fissuring. Chromium, tungsten and vanadium materially increased the resistance, while other elements such as niobium, tantalum, titanium, zirconium and thorium, which form stable carbides, have also been proposed.

Lead

Ease of fabrication, coupled with high resistance to sulphuric acid, retains for lead a high position as a structural material. The effect of impurities on resistance has been studied in detail. A recent specification stipulates a flash point of not less than 300° C., indicating the remarkable purity of the metal now available, actually 99·995%. A fine grain structure has been established as necessary where the maximum corrosion resistance is concerned. While it is still doubtful regarding the advantages of small percentage additions of copper and nickel, tellurium in less than 0·1% offers marked improvement in properties. Tellurium gives a finer grain structure than either copper or nickel; it raises the temperature of spontaneous crystallisation so that the lead can be cold-worked; in addition, the lead becomes markedly more resistant to corrosion. The refined grain insures more uniform distribution of deformation, a fact which should be of great importance where lead vessels are subject to vibration.

Copper

The demand in the United States for copper and its alloys has been enormous in recent years, particularly in the brewing industry. The addition of 15% zinc gives resistance to most acid and salt solutions superior to that of the bronzes, while the latter, when aluminium is incorporated, are finding applications where strength and resistance to abrasion and corrosion are required. For handling hydrochloric acid of all strengths in the cold and up to 20% at 150° F., in the absence of air and steam, the alloy containing 1—5% silicon and 1—2% manganese, tin, or iron is noteworthy.

Nickel

The purity of nickel and its resistant quality have contributed towards the increasing use of this metal and its alloys. In its pure form, or as nickel-clad steel, it is finding increasing application in the handling of caustic soda, anhydrous ammonia, and in foodstuffs manufacture. It is claimed that nickel plating on steel is not entirely satisfactory where corrosion resistance is required, nor is spraying with the metal on steel. With certain non-ferrous metal bases, however, good results have been reported.

Of the copper-nickel alloys, all of which show good corrosion resistance, Monel metal is the most important, possessing a degree of resistance surpassed by few other metals. In addition, the mechanical properties and ease of fabrication are equally important features. The addition of 3·45% of aluminium to the alloy enhances its strength and hardness after heat-treatment, without diminishing its powers of resistance. Mention is made of Hastelloy, containing 58% nickel, 20% molybdenum, 20% iron, with the addition of chromium and tungsten in certain cases. This alloy, which can be welded, offers resistance to chlorine and to hydrochloric acid of all concentrations up to 70° C.

Aluminium

The film of oxide to which aluminium owes its corrosion resistance has been decreased in permeability by impregnating the coating with corrosion-inhibiting substances, and has been artificially produced in a tenacious form by several well-known processes. An otherwise highly reactive chemical element has thus been made available in increasing quantities for the construction of chemical plant, in particular for handling synthetic nitric acid, anhydrous sulphur dioxide, gaseous and liquid ammonia, and acetic acid, and for the manufacture of varnishes and fatty acids, and over a wide range of the foodstuffs industry.

The rapid attack of aluminium by alkaline liquids, halogen and halogen acids, still calls for attention. The

first-mentioned attack has to some extent been mitigated by adding small quantities of sodium silicate, but there appears to be no satisfactory inhibitor as yet for free halogen acids. It is fortunate, incidentally that the corrosion effect of many anhydrous substances is greatly reduced by a trace of water. The technique of welding this metal does not yet appear to have reached the same advanced stage as the ferrous metals, and the formation of cracks at the weld is still too common in aluminium plant. Of the alloys, the development of Duralumin and γ-alloy are pointers to future efforts along the line of resistance to specific media.

Rarer Metals

Recent changes in the economic position have broadened the use of silver in the chemical industry. Equipment is usually made of the fine metal which is easily fabricated and has high scrap value. It is now available in the form of linings as movable, electroplated and clad-metal. For the preparation of pure organic products such as phenol, acetic acid, in the recovery of solvents, and in the foodstuffs industry, silver is finding increasing application. The resistance of the platinum group to heat and acids is well known. Alloys with iridium, osmium, rhodium, ruthenium, all of them solid solutions, offer increased resistance to aqua regia. Gold and its alloys with tantalum and platinum are used in the rayon industry, where resistance to corrosion, abrasion and heat is required.

Corrosion

With regard to corrosion, the chemical engineer must concern himself with the effect of atmosphere, differing in country and city, indoor and outdoor, as with resistance to chemical media. It has been confirmed that moisture is the primary factor in atmospheric corrosion. For the corrosion product of each metal there appears to be a critical humidity above which condensation occurs—about 100% for copper, bronze, chromium and iron, and about 85% for zinc, brass and nickel.

The effect of carbon dioxide, of calcium carbonate, magnesium carbonate, and sodium salts present in natural waters may have serious effect in the formation of films due to deposition under certain conditions. Where no film is formed, corrosion may ensue. Equilibrium relationships between the amount of carbonate in solution and *p*H value afford means of predicting the effect of the water, e.g., on pipes, or of determining the methods for successful pretreatment of the water. The electrochemical nature of soil corrosion receives increased attention, and the effect of type of soil and its particle size has been investigated. Some of the best methods of protection against corrosion by atmosphere, water and soil are to be found in metallic coatings.

Much information is available with regard to the action of the commoner chemical products on most metals and alloys, in some cases provided by manufacturing concerns. The chemical engineer will still find, however, that the best means of satisfying himself in any specific instance is to expose his metal or alloy to the action of the corrosive medium under conditions similar to those holding in his process. Furthermore, there is still need for the general adoption of quantitative expression for assessing corrosion, such as has been adopted in Germany.

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conjunction with nickel or chromium, or both, and this was particularly apparent in the normalised condition. The impact values obtained for the carbon-molybdenum steel were somewhat lower than were expected, but this steel was found to have a duplex structure indicating improper deoxidation or rolling, and it has been shown that incomplete oxidation tends to reduce the impact strength at low temperatures. It would therefore appear to be advisable to use low molybdenum steel in the fine-grained state if satisfactory resistance to shock is to be obtained at temperatures lower than normal.

Low-Temperature Impact Properties

A REVIEW of available literature shows that published information is notably deficient as regards the impact properties of steel at very low temperatures, and is, in some cases, of questionable value because of failure to standardise or control testing conditions. An investigation therefore carried out recently by A. J. Herzig and R. M. Parke[1] on this subject is therefore of interest and value. The investigation was inaugurated to obtain sub-zero impact strengths of a carbon-molybdenum steel containing 0·15% carbon, 1·00% manganese, 0·22% silicon, and 0·47% molybdenum, and also of several standard carbon and alloy standard steels; and in particular to determine what steels could meet an arbitrary minimum Charpy impact strength of 10 ft.-lb.

The Charpy test specimen was selected in preference to the standard Izod bar, due to the greater rapidity with which a Charpy bar can be transferred from the cooling bath to the impact-testing machine and fractured. A 45° V-notch Charpy impact specimen, machined to the A.S.T.M. Tentative Standard, was used throughout the investigation, and all specimens were broken on a 40-mm. span in a pendulum type impact machine of 120 ft.-lb. capacity. The weight of the hammer was 23·571 lb., and the length of the pendulum was 31·497 in. The hammer was released from a point 20° off the vertical position, and, swinging through an angle of 160° before striking, struck the specimen with a velocity calculated at 18 ft. per sec.

Tests were carried out at temperatures down to −190° C. For temperatures down to −70° C., the cooling medium used was a mixture of alcohol and solid carbon dioxide. A solution of liquid air, alcohol and solid carbon dioxide was used to obtain a temperature of −90° C., while a temperature of −190° C. was made possible by the use of liquid air alone. Test specimens were held at the sub-zero temperature for ½ hour before testing, and between 1 and 2 secs. elapsed from the time a specimen was removed for the cooling media and the time the blow was struck. Any rise in temperature which occurred in this short period was regarded as negligible. Each steel was tested after three different heat-treatments, viz.: (1) normalised at a temperature suitable to the particular steel, (2) quenched and tempered to give a Brinell hardness of approximately 200, and (3) quenched and tempered to give a Brinell hardness of approximately 300. As it is generally conceded that the impact test is one of the most difficult physical tests to perform on metals, three breaks were found necessary to establish a reliable impact value for each test condition, and in several of the tests, particularly at the lowest temperatures, as many as six fractures were made, and the results averaged.

A comparison of the results obtained emphasises the importance of heat-treatment in improving the low-temperature impact strength of steel, and shows that alloy steels are superior to plain carbon steels in this respect. Of the 12 steels investigated, satisfactory low-temperature impact values in excess of 10 ft.-lb. at −70° C. were obtained for 10 of the steels in the normalised condition. In the quenched and tempered condition to give 200 Brinell hardness, all the steels except one gave satisfactory results, while in the quenched and tempered condition to give 300 Brinell hardness, all the steels except the carbon-molybdenum and two others had satisfactory low-temperature impact properties.

As the steels selected for investigation varied in carbon content, it was impossible to measure quantitatively the effect of individual alloys on low-temperature impact properties. In the case of molybdenum, however, this element appeared more effective in improving impact strength in steel at low temperatures, when used in

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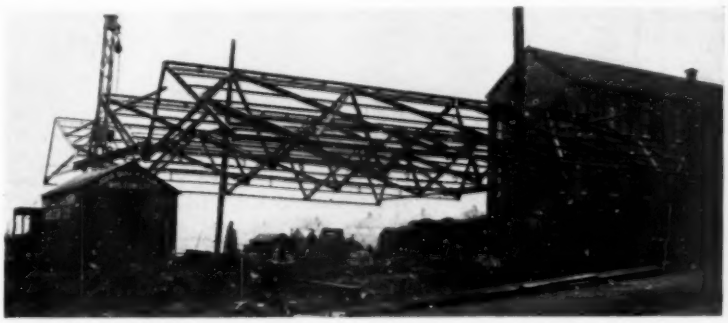
1 *Metals and Alloys*, 1938, Vol. 9, No. 4, pp. 90-93.

Progress in Electric Arc Welding

A useful contribution to the progress of welding is the James F. Lincoln Arc Welding Foundation, which 18 months ago instituted a programme of awards for the best methods for effecting savings in industry by the use of arc welding. The awards have now been made, and in this article brief summaries of some of the successful papers, submitted by English authors, are given.

TO encourage and stimulate scientific interest and study, research and education in the arc welding industry, and to promote development in the knowledge of design and the practical application of arc-welding processes, a competition has been held under the auspices of the James F. Lincoln Arc Welding Foundation, and the awards have now been decided. Altogether, 382 awards have been made, the amounts ranging from $101·75 for honourable mention, to the Grand Award of $13,941·33. Subjects of studies in the 44 divisions of the Programme represented practically every product and structure of industry.



Small northlight roof, 60 ft. × 71 ft., for laundry; fabricated on the ground and lifted to columns in one piece.

A 300 ft. × 175 ft. northlight roof for a factory with a clear floor area of 100 ft. × 175 ft.

The first award went to Mr. and Mrs. A. E. Gibson, the former is president of the Wellman Engineering Co., Cleveland, Ohio. Their paper is an outstanding treatise on all the elements required to assure the business and technical success of all users of welding throughout industry. Many engineers and designers of Great Britain are among the prize winners; the second Grand Award was gained by Messrs. Anant H. Pandya and R. J. Fowler, of Diagrid Structures, Ltd., Horseferry House, Westminster, London, S.W. 1. This joint award of $11,397·06 was paid for their paper, "All Welded Grid Applied to Plane and Spatial Structures," submitted in the Building Division of the structural classification of the Programmes. Ten other awards were made for papers submitted by United Kingdom authors, including $1,322·82 to Edward F. Spanner for his paper on "Welding Thimble Tube and Watertube Boilers"; $305·26 to Cyril Helsby for his paper, "Arc Welded Pier"; $305·26 to Arthur Kershaw for his paper, "Welded Design of a Single Housing Planer"; $203·51 to R. Sherman, and the same amount to Henry P. Print; $152·63 each to E. Christie and L. T. Duff; $152·63 jointly to Wm. H. Whittall and Frank N. Buxton; $101·75 to Thomas G. Grisenthwaite, and the same amount jointly to Hugh B. Fergusson and Edward F. Burford.

The All-welded Diagonal Grid applied to Plane and Spatial Structures

By ANANT H. PANDYA AND R. J. FOWLER.

One of the most important developments in modern methods of steel construction is the perfection of the technique of electric arc welding. The introduction of welding leads to "continuity" at the connections, which makes it imperative for the designer to use somewhat complex methods of stress analysis. The general effect of this, however, is to reduce forces and moments on members of a structure and thus lead to economy in materials and cost.

In order fully to exploit all the advantages of this new technique, it has been found necessary to explore new methods of arranging structural members. One method, fully described in the original paper, comprises a diagonal system of beams arranged in two parallel sets equally spaced and intersecting at 90° or nearly so, and rigidly connected at the junctions or nodes. Such a layout gives beams of varying span which, when connected monolithically, produce a co-operative action and tend to equalise moments and shear forces on all beams. The diagonal arrangement of grid beams also has the following advantages in the case of plane grids suitable for floors and flat roofs:—

(1) A shallower depth of construction.
(2) A plane soffit for floors or flat roofs.
(3) Economy due to the exploitation of continuity.
(4) Rapidity and ease of construction due to standardisation.
(5) Use only of rolled instead of plated sections to cover large spans.

Additional advantages in the case of spatial grids forming roof structures are:—

(6) A complete absence of bracings, tie-rods, etc., below the planes of the roof structure.
(7) Reduction in the area of steelwork to be painted and in maintenance costs.
(8) Cubic capacity of the structure is increased because of the absence of internal columns, ties, bracings, etc.

It may be mentioned that the welded diagonal grid provides a solution to a variety of structural problems, and is only made possible in structural steelwork by the advent of electric arc welding.

Principles of Detailing and Erection.—The main factors governing the choice of sections and detailing of connections are similar to those in orthodox welded construction. For connections, the forces and moments to be transmitted, together with the proposed method of erection, must be

considered, and for members—suitability for welding, considerations of workmanship and handling and relative costs of various sections are important.

Regarding the actual types of welds used to connect members, butt welds and fillet welds are used. The former is generally the most economical weld to develop the strength of a plate or section presenting direct stress flow and obviating stress concentrations. It is used at the ends of grid members where the stress often reaches the permissible stress for the material.

Sections most commonly used are rolled steel joists for grid beams for both floors and spatial grids. For the latter, small rolled steel joist purlins, welded into continuous lengths and so designed as continuous beams, are laid direct on the top flanges of the grid beams and fillet welded

Part of floor, 400 ft. long × 22 ft. 6 in. span, for gallery in aircraft factory.

Continuous pitched roof, 90 ft. × 115 ft. span, for aircraft factory. A lavatory block, producing load of 1 ton per foot ram is carried in the centre valley.

to them. Edge beams and gable ties for convenience of detailing are usually rolled steel channels placed with their backs towards the grid beams.

The aim in detailing diagonal grid connections has been to reduce to a minimum the amount of work carried out on rolled sections, and to make any preparation necessary for connections on splicing plates alone. For instance, grid beams are for butt welds cut dead square at their ends, notched at the centre of their lengths for plane intersections, and drilled with two holes in the web at each end for location and assembly purposes. These operations may be efficiently carried out in the field, greatly reducing the cost of the work.

Connection details, whether for arched, northlight, ordinary pitched, and plane grids are standardised; which is especially economical in drawing office costs and leads to fabrication and erection savings.

Erection is generally carried out by fabricating on the ground as large sections as can conveniently be lifted. In the case of plane grids, they may be assembled and welded complete on trestles and then lifted on to stanchion seats. Similarly, spatial grids may be assembled in slopes, bays, or even two or three bays on the ground, and lifted in one piece.

The accompanying illustrations, reproduced from photographs kindly supplied by Messrs. Diagrid Structures, Ltd., show some examples of the grid structures described in the paper and recently erected in Great Britain.

Welding as Applied to Thimble Tube and Water Tube Boilers

By EDWARD F. SPANNER.

This paper, divided into six main sections, deals with applications in special types of boilers. The first section is concerned with the designs of Spiralflo boilers and water heaters invented for the purpose of waste heat recovery from Diesel engine exhaust gases, waste gases from industrial furnaces and similar plants. Different arrangements of these are described, and attention is drawn to the fact that the commercial development of these boilers has only been made possible by the use of electric welding. The second section describes Steddyflo boilers, in which waste heat recovery is secured by the use of closely packed nests of short water tubes; here again the designs are only practicable by the extensive use of electric welding. The next section was devoted to direct-fired boilers of Spiralflo type, in which, apart from joints remote from the fire space, all connections are made by means of electric welding. These boilers are said to have proved exceptionally satisfactory in service, giving very high outputs on small weights, overall sizes, and heating surfaces.

Patent composite Spiralflo-Steddyflo boilers were discussed in the fourth section, the combination of this direct-fired boiler and waste-heat boiler having resulted in the production of very neat and efficient composite boilers which are stated to be very satisfactory in service. The fifth section of the paper indicated a number of important directions in which these particular units could be used to improve the efficiency of heat recovery when working in co-operation with horizontal boilers of older types, such as Lancashire and Cornish boilers, etc. In this connection attention is directed to the economy in construction and the linking up of the various units dependent upon the extensive use of electric welding.

The paper concludes with a consideration of some of the problems encountered in building welded boilers of the types mentioned and the fact emphasised that without electric welding the development of these special designs would have been quite impracticable.

Heat-treating Lathe Bed Ways

A PROCESS has been developed which permits the selective heat-treatment of the ways of large lathe beds. In the new method, heating and quenching is carried out in one operation by means of a specially designed oxy-acetylene torch equipped with a series of water jets for quenching, which follow immediately behind the burner tip. In this flame-hardening process the lathe bed is immersed in a tank of water to a point just below the ways, and a motor-driven mechanism draws the heating and quenching unit at a uniform speed over the ways. Only one pass over the bed is necessary. The rate of travel of the burner tips over the bed ways depends on the thickness of the bed, varying from 3 in. to 6 in. per min.

Test strips corresponding to the different section of ways are used to determine the proper burner tips, the amount of heat to be applied, and the rate of travel. The depth of penetration of the hardened surface can be varied from $\frac{1}{8}$ in. to $\frac{1}{4}$ in., and the Brinell hardness is raised from 225/240 as cast up to 575/590 after this treatment. The lathe beds on which the process has been developed are cast in nickel-chromium cast iron having an average composition as follows:—T.C., 3·00%; Si, 1·70%; Mn, 0·85%; Ni, 1·50%; Cr, 0·30%.

The Creep of Metals under Static and Repeated Stresses

The rate of creep of metals at elevated temperatures was discussed by Professor F. C. Lea at a recent meeting of the Midland Metallurgical Societies, in which he referred to early experiments on metals at ordinary temperatures. He emphasised the value of creep tests, and stated that short time tests gave approximately relative values of steels to meet new conditions.

PRELIMINARY experiments quickly indicated that the investigation of the phenomenon of creep would require years of research, and involve a large number of workers. Initially, experiments were carried out on a number of metals at ordinary temperatures. Taking, for example, a specimen of mild steel, the fundamental properties of which are so well known, the creep in the neighbourhood of the yield point was investigated, and it was shown that when yield occurred at a particular stress, increasing strain or creep might continue for some hours, but it seemed quite certain that this creep ceased. Further, at stresses beyond the yield point, but well below the breaking stress, creep would continue for long periods, but would eventually cease. For instance, a mild steel containing 0·14% carbon, heat-treated at 825° C., exhibited creep at 14 tons per sq. in. ; at first irregularly, and then very slowly, but steadily, for almost 4 hours. As the stress was raised, creep took place for several hours at 15 and 16 tons per sq. in., and over until, at 25 tons per sq. in., the specimen developed creep until it finally broke in a little over 5 hours, the total time of loading after yield being 42 hours.

Another specimen normalised at 890° C., was loaded gradually to 26·4 tons per sq. in., and the load was kept constant for 14 days. During the last four days no movement was observable by an extensometer capable of measuring extensions of less than 1×10^{-5} in. With a sample of stainless steel, of the 18/8 type, small creep took place at 6 tons per sq. in., but after 20 hours no creep could be detected. At 10 tons per sq. in., creep apparently ceased after 60 hours ; at 14 tons per sq. in., comparatively rapid creep continued for 106 hours, and had probably just ceased; at 40 tons per sq. in., after 672 hours, creep could not be observed, but at 44 tons per sq. in. the specimen broke in 10 mins. If broken quickly, a similar specimen would not break at less than 55 tons per sq. in.

Preliminary experiment at high temperatures showed that very long times would be required to determine the stress at which rate of creep would become so small that it could not be observed, and it also became apparent that very sensitive strain-measuring devices were necessary, and that control of temperature of test was of the greatest importance. Suppose a specimen 2 in. long is to be tested, and the rate of creep is $\frac{1}{10^6}$ in. per inch per hour, then the elongation in, say, 10 hours will only be 0·00001 in. per inch. Suppose now the temperature of the test changes by 2° C., then the change in length of the specimen will be 0·000028 in., or much greater than the change due to creep. It appears, therefore, that changes of temperature during the test must be controlled within very narrow limits or comparatively long periods of time must be taken. If one degree change of temperature occurs, then for a creep strain of $\frac{1}{10^6}$ to be observed with any confidence, the time of observation must be greater than X hours when $\frac{X}{10^6}$ is greater than 0·000014, or X is greater than 14 hours.

There are two important points to be noted about creep tests such as are being described. The first is : what is the total strain produced in a given time ; and secondly, what is the final rate of creep, or is the final rate of creep less than some specified rate ? In the case of material for boiler tubes, the increase of diameter per inch diameter of tube was $\frac{9}{10,000}$ of an inch, and the final rate of creep was less than 10^{-7} in. per inch per hour. If this rate of creep remained constant, the boiler could work 100,000 hours—that is, about 12 years' continuous work without the tube increasing in diameter another hundredth of an inch.

The creep was comparatively large on first loading to a particular stress and it is pertinent to ask the obvious question arising, " What is the reason for the diminution in the rate of creep ? " The answer appears to be that the straining work hardens the material. The next question which arises is, " Will the prolonged heating produce changes in the metal that will allow the rate of creep to increase again, and be such as will lead to failure ? " That changes in the properties of steels do take place by prolonged heating at temperatures at which modern steam plants work is now well known. Spheroidisation of the pearlite of carbon steels takes place, and this leads to an increase in the rate of creep at a particular stress. Further, changes take place in certain alloy steels which lead to embrittlement, and to the very considerable lowering of the impact value obtained from the Izod test. Experience shows, however, that provided stress and temperatures are kept below certain values, creeps are so small that they are not observable in practice and do not lead to failure.

From what has been said it will appear that the ordinary method of defining the breaking stress of a material and using some fraction of this in designing parts of structures or machines to work at high temperatures, cannot be satisfactory, and it becomes necessary to define what may be called a " limiting creep stress," or a " limiting creep rate " at a particular stress, and also the maximum possible strain in the assumed life of the plant. Below certain temperatures the limiting creep stress, or the stress below which creep ceases, has, Professor Lea believes, a real meaning, but above certain temperatures it seems possible that creep will be continuous, even at small stresses.

The creep of metals has been shown to depend upon the length of time any particular stress is applied. If, therefore, a specimen is subjected to repeated stress cycles, it might be expected that the resistance of the material would depend upon the periodicity of the cycles, and if creep did occur, the form of the creep curve would be very similar to that under static stress. It was shown that e.g., in a specimen of steel containing 0·46% of carbon, subjected to cycles of tension and compression at 2,000 cycles per minute, very small extensions take place, and, finally, a specimen broke. At a stress range of plus or minus 14·2 tons per sq. in., and at a temperature of 396° C., nearly 6 million repetitions were resisted, and at ± 15·2 tons per sq. in., and 408° C., the specimen broke at less than 250,000 repetitions. In the case of a spiral spring, tested at 400° C. at a rate of oscillation of 160 cycles per minute, when the mean stress was 20 tons per sq. in., and the range of stress 15 tons per sq. in., the spring crept and broke after 5 million repetitions. When the mean stress was 8 tons per sq. in., and the range 12 tons per sq. in., there was creep, but it became less and less, and fracture did not occur in 8 million repetitions.

When the cycles are repeated slowly, say two or three per minute, then the behaviour of the specimen is very similar to that under a steady load. Under cycles of stress in tension, from 0 to X tons per sq. in., at the rate of $2\frac{1}{2}$ cycles per minute, the form of the creep curve is not very different from that under a static test. At 435° C. a mild steel which had a tensile strength of 28 tons per sq. in. will, under a static load of 6 tons per sq. in., settle down to a steady creep of the order of 10^{-7} in, say, 20 to 30 days. Under repeated tensile and compressive stress of 2,000 cycles per minute, it will withstand a range of plus or minus 14 tons per sq. in. for many millions of reversals, but under $2\frac{1}{2}$ cycles per minute a direct tensile range of from 0 to 8 tons per sq. in. would probably cause creep-and fracture in a few months.

Creep can take place and lead to fracture under static stresses at temperatures above 300° C., at stresses much less than those which will break the specimen when loaded quickly. At 300° C. the stress at which the rate of creep becomes less than an allowable amount for, say, all types of pressure vessels, is about half the tensile strength at that temperature, while at 500° C. it is less than one-third of the tensile strength at that temperature.

In designing plant or machines to work at temperatures well above the atmospheric temperature, the designer must carefully consider what possible maximum strains he can allow, and what the final life is likely to be. Working stresses must then be chosen consistent with these. Some materials, as already remarked, though having fairly good creep-resisting properties at temperatures of the order of 500° C., or 600° C., may embrittle badly, as, for example, some of the nickel-chrome steels and some of the so-called heat-resisting steels. The relative values of steels to meet any particular new condition can be approximately obtained by short time tests, but as yet no short time test has been developed that will indicate the final rate of creep that, after a certain time at a particular stress, the metal will settle down to, or in other words that will determine what will be the limiting creep stress, or the stress at which the rate of creep will become less than a specified rate applicable to a particular design. A very large amount of work is now going on in the laboratories of many countries and the effect of impurities on the creep properties are being investigated. The creep properties at various temperatures of many well-known steels are now known to be within temperatures for practical purposes.

Symposium on Protecting Metals against Corrosion

THIS publication comprises four technical papers presented at a meeting of the Detroit section of the American Society for Testing Materials. The symposium includes a paper by H. W. Gillett on "Corrosion-resistant Alloys," one by C. E. Heussner on "Protection of Base Metals by the Use of Metallic Coatings," a third by R. J. Wisshing on "The Pre-treatment of Metals," and a discussion by J. L. McCloud on "Corrosion Protection by Means of Organic Coatings."

In a symposium of this kind it is impossible to include complete and detailed information on all the subjects presented, but the articles do cover, in a broad sense, and in many cases the pertinent details, desirable in selecting protection against corrosion for specified uses. The articles cover not only the advantages to be gained by protection but also the limitations of the various processes both as to quality of finished products and problems of processing. Many instances of cost comparison are given. All the authors of the articles contributed are authorities in the respective fields covered, and although they are more closely associated with the automobile industry, the subjects are so presented that the information given will be readily applicable to many other industries.

Published by the American Society for Testing Materials, 260, So. Broad Street, Philadelphia, Pa., U.S.A. Price 50 cents per copy.

Reviews of Current Literature

The Elements of Ferrous Metallurgy

THIS book has the commendable feature of covering the field of ferrous metallurgy without taking up valuable space with excessive detail. The authors state that this is an elementary treatment of the subject, but this is rather a modest statement, for this work includes material that takes cognizance of the advances in ferrous metallurgical technique, new theories and new alloys.

The first chapter, on fundamentals, would alone be of great value to the student and the remaining chapters follow in logical sequence, from blast-furnace principles and operation to foundry considerations. The Bessemer, open-hearth, and electric processes are described in detail, and these chapters, in common with most others, include valuable data on the processes concerned.

Wrought iron, cementation and crucible processes, and ingots are dealt with comprehensively, and one of the most valuable chapters in the book is that devoted to the iron-carbon system. Definitions of terms are given as and when they occur, but the purpose of the book would have been even better served if more explanation had been included of space lattice or atomic arrangement. Elsewhere, it is not assumed that the student knows all the terms, or their significance, but here that factor is given less prominence. In the same chapter there is an illustration of a cored crystal structure, but the example chosen is that of a cast zinc-aluminium alloy.

The mechanical treatment of steels forms a straightforward chapter and contains useful information on rolling processes; the constitution and heat-treatment of carbon steels is very clear, indeed, while the chapter on the elements in carbon steels contains data that will be readily understood by all students and steel workers.

The subsequent sections on analyses and uses of carbon steels, details of alloy steels and their uses, and cast irons also form valuable reference material, and add considerably to the value of this book. The chapter on the foundry is not a long one, but is useful and up-to-date. A little more space could, however, have been devoted to this subject with advantage, although the subject is so vast that it would be difficult to know just what to include and what to omit, having regard to the essential inclusion of the other aspects of ferrous metallurgy already mentioned and within a book of reasonable size.

The book is abundantly illustrated with photographs, line drawings and diagrams, and is one that we can recommend for those who wish to study this science and to keep abreast of modern developments.

By Joseph L. Rosenholtz, Ph.D., and Joseph F. Osterle, Ph.D.; published by Chapman and Hall, Ltd., Covent Garden, London, W.C. 2. Price, 15s. net.

Manganese Deposits in Bashkiria

THE Soviet republic of Bashkiria is very rich in natural resources. Her deposits of manganese are estimated at 5,700,000 tons. The iron ore of the Tukansky deposits alone are estimated at 40 million tons. Twelve prospecting parties sent out by the Geological Trust of Bashkiria are carrying out further prospecting work. Near the villages of Kusimovo and Yalimbekovo, in the Abzelilov district, rich deposits of manganese ore have been found said to run into 1,100,000 tons. Large deposits of manganese ore have also been found in the Uchalin and Beloretsk regions.

The Uchalin region has also large deposits of the useful mineral, talc. The deposits of talc in the Kozmodemyan and Keryabin districts of this region alone are estimated at 300,000 tons. In the Makarovsk district deposits of high quality phosphorites, said to run into 25–26 million tons have been found. Of great industrial importance, too, are the deposits of copper, lead, nickel, cobalt, scheelite, found in the aforementioned and other districts of Bashkiria.

Reducing Corrosion and Erosion in River Structures

An investigation, designed to develop means for the prevention of corrosion and erosion of various structures and mechanical devices which operate in acid-polluted water, is discussed and specifications of materials are given which have proved successful.

VERY severe corrosion-erosion conditions exist in the Monongahela River as a result of highly acid sand-bearing water and the high maintenance cost of river and harbour structures has necessitated an investigation in an effort to develop means for the prevention of corrosion and erosion of the various structures and mechanical devices which operate part or all of the time in this acid-polluted water. Research and experimentation for corrosion-erosion-resisting materials have been carried out in the Pittsburgh Engineer District, and some particulars of the work and the results achieved are discussed by Dieffenbach.* The district embraces industrial Pittsburgh, and the river banks within the area are lined with mills, mines and factories concerned with a wide range of industries. These factors have made the Monongahela River the greatest freight-bearing river in the world, but they have also contributed greatly to the problem of construction and maintenance of the navigation aids, including locks, dams, and various pieces of floating plant required in this work.

The chief sources of acid water pollution, causing the destructive corrosion and erosion, are mine water waste, waste pickle solution, and discharge and waste from iron and steel mills, rolling mills, oil refineries, paper mills, tanneries, and oil wells. The largest single source of pollution is probably abandoned and operating coal mines from which flow abundant supplies of subterranean, highly acid water. A typical analysis of the river water is impossible because of the great variation in the quality of water from time to time and at various places as a result of the many sources of pollution. The acid content may even vary at different widths of the river.

An ultimate water analysis of the Monongahela River (at McKeesport, Pa.) is as follows (in parts per million) :—

Colour	Tan
Appearance	Clear
Alkalinity	5·0
Acidity (phenolphthalein)	45·0
Free acid as H_2SO_4 (methyl orange)	11·0
Chlorides as Cl	15·0
Fe	1·10
Si	13·0
Fe_2O_3	1·6
Al_2O_3	7·4
$CaSO_4$	157·0
$MgSO_4$	69·0
SO_3	166·0
Total solids	287·0

Another miscellaneous source of water pollution is the absorption of acid anhydrides from the air. Anhydrides such as sulphur dioxide are given off in smoke by industries involving large-scale chemical reactions with waste fumes, such as the iron and steel industries, coke and coal industries, lead works, galvanising plants, paper plants, etc. So acute is air pollution in some industrial sections that hot-dipped galvanising on steel lasts only for three to six months.

Paint made in accordance with specifications given in the report has been used successfully in the prevention of moderate corrosion and erosion on structures such as the lock gates. The paint referred to has an original cost less than red lead-linseed oil paint, and costs less to apply because of the free-flowing properties resulting from the flowing agents incorporated in the vehicle. In more severe conditions, where mechanical wear and abrasion exist and where mechanical strength is a prerequisite for preventing corrosion and erosion, it is necessary to use materials with corrosion-erosion resisting properties and other necessary physical properties.

For the lock-gate valves, copper-molybdenum cast iron of the following composition has been found to give materially better results than grey cast iron or steel castings ; a lock-gate valve of this composition has been in this service for 2½ years without any noticeable corrosion-erosion :—

Chemical analysis, % :—	
Total carbon	2·40–2·60
Combined carbon	0·60–0·80
Silicon	1·90–2·10
Manganese	0·40–0·55
Sulphur	0·04–0·08
Phosphorus	0·15–0·19
Copper	0·80–1·00
Molybdenum	0·30–0·40
Physical properties :—	
Ultimate tensile strength and yield-point lb./sq. in.	55,000–65,000
Transverse strength arbitration test-bar (standard A.S.T.M. bar), 12 in. centres, lb.	5,300–6,000
Modulus of elasticity, lb./sq. in.	22,000,000–30,000,000
Single shear test, 1 in. round bar, lb./sq. in.	40,000–50,000
Weight per cub. in., lb.	0·266–0·268
Brinell hardness	220–240

For use in hydraulic turbine runners, valve frames, speed rings, and other similar applications, nickel-copper-chromium cast iron of the following composition has given excellent results :—

Chemical analysis, % :—	
Total carbon	2·30–3·00
Silicon	1·00–2·00
Sulphur	0·12 max.
Phosphorus	0·30 max.
Manganese	1·00–1·50
Nickel	13·0–16·0
Copper	5·00–7·00
Chromium	2·0–3·5
Physical properties :—*	
Ultimate tensile strength, lb./sq. in.	21,000 min.
Transverse strength (1·20 in. dia., 18 in. centres), lb.	1,750 ,,
Deflection, in.	0·20 ,,
Brinell hardness No.	120 ,,

* Test-bars to be made in accordance with dimensions given in Federal Specification QQ-I-651.

Corrosion-resisting steel is used for many applications to prevent corrosion-erosion. The austenitic types have been found very resistant to corrosion because of their stainless properties, and to erosion because it work hardens and the scouring effect of the suspended sand in the water seems to harden the steel with use. This material is also available rolled in thin sections clad to mild carbon steel ; it has been used to good advantage on certain valve blades for surfaces where severe corrosion-erosion occurs. This material can be obtained rolled, forged, or cast. The specification for this particular type of steel as used by the Pittsburgh Engineer Department is as follows :—

Chemical analysis, % :—	
Carbon	0·07 max.
Chromium	16·00–20·00
Nickel	7·00–14·00
Molybdenum*	2·00– 4·00
Physical properties :—†	
Tensile strength, lb./sq. in.	90,100–100,000
Yield-point, lb./sq. in.	40,000– 50,000
Elongation in 2 in., %	50–60
Reduction of area, %	60–75
Brinell hardness No.	170–200
Modulus of elasticity, lb./sq. in.	28,000,000–30,000,000

* Molybdenum is included to prevent graphitic precipitation.
† Material shall be cold-drawn and pickle-finished.

Valve stems were made of this material and installed in the Monongahela River for three years without any noticeable corrosion or erosion effects.

* Ferd Dieffenbach. *Ind. Eng. Chem.* Vol. 30, No. 9. Pp. 1,014–1,020.

The corrosion-resisting steel just described cannot be hardened by heat-treatment, and in cases where it is necessary to have corrosion resistance combined with uniform and relatively high hardness, such as is required in a gate pintle rotating in bronze, the following martensitic type of corrosion-resisting steel is used :—

Chemical analysis, % :—	
Carbon	0·12 max.
Sulphur	0·45 max.
Chromium	12·00–15·00
Molybdenum	0·50 max.
Physical properties :—*	
Proportional elastic limit, lb./sq. in.	65,000 min.
Yield-point, lb./sq. in.	120,000 ,,
Ultimate tensile strength, lb./sq. in.	160,000 ,,
Elongation in 2 in., %	5 ,,
Brinell hardness No.	310 ,,

* This material may be obtained in rolled, forged, or cast form.

For bearings operating with steel in acid river water, with little or no lubrication other than the water, a bronze has given excellent results ; it is centrifugally cast from virgin metals to give the following properties :—

Chemical analysis, % by weight :—	
Copper	79·25–80·25
Tin	9·50–10·50
Lead	9·50–10·50
Phosphorus	0·30– 0·50
Other elements	0·25 max.
Physical properties :—	
Ultimate tensile strength, lb./sq. in.	30,000 min.
Yield-point in tension, lb./sq. in.	22,000 ,,
Elongation in 2 in., %	6–8
Brinell hardness No.	75–80
Compression deformation limit, lb./sq. in.	18,000 min.
Permanent set in 1 in. under 100,000 lb. load, in.	0·20–0·30 max.

Extraction of Oxide Inclusions in High-Carbon Iron

INCLUSIONS, whether in steel or cast iron, have been the cause of no little research. Whatever their nature or composition, they may be harmful, and a successful determination of their character is important as a means of reducing the number or preventing their presence. Recent demands for better cast irons have led to many metallurgical investigations concerning the factors affecting their physical properties. It has been observed that the mechanical properties of grey cast iron may not be the same even with the same chemical composition, pouring temperature, and cooling rate. The mechanical properties that are to be controlled are dependent upon the continuity of the matrix, which is in turn dependent upon the size, distribution, and amount of the graphite flakes. Assuming that the superheating, cooling rates, and chemical composition can be controlled accurately enough to produce uniform castings as regards mechanical properties, it appears that certain irregularities are caused by a substance which affects graphitisation and is not obtained in the chemical analysis.

Several hypotheses are at present under consideration, which suggest that graphitisation is dependent upon the presence of non-metallic inclusions which act as a nuclei for the formation of the graphite flakes during the solidification of the iron. So far, however, the opinion that the inclusion theory explains the variation of graphitisation characteristics of cast iron is purely a hypothesis with practically no data to substantiate it. If inclusions are associated with the graphite they are of sub-microscopic size, making visual examination impossible, and the microscope is no assistance in their study. Recently an investigation has been undertaken by F. W. Scott[1] to develop a method for the extraction and determination of oxide inclusions in cast iron with a view to obtaining data which will enable a better understanding to be made of the phenomenon referred to.

A review of the various methods for the extraction of inclusions and particularly oxides in steel or low carbon products show that there is not agreement that any one method is most accurate and can be relied on to give good results under all conditions. Opinion is divided as to whether methods depending upon the reduction of the oxide substance at high temperatures by either carbon or hydrogen, the vacuum fusion method, or methods which endeavour to dissolve the metallic iron from the oxide, leaving the oxide as a residue, are to be preferred. A consideration of all the methods available appeared to show that the electrolytic iodine, method of extraction, whereby the metallic constituents are separated from the non-metallic constituents and the oxides determined in the non-metallic residue, offered several distinct advantages in studying the oxides in cast iron, so that such a method with a number of small changes was adopted in investigating the oxide inclusions in high carbon cast irons.

In preparing various alloys for the oxide determinations, a low metalloid iron was first produced by melting Armco iron in a carbon crucible in an electric furnace. This iron was used as a base for the production of the other alloys, and contained 0·033% carbon and a small amount of manganese, phosphorus, and sulphur. The surface of this iron was oxidised, and the iron itself contained appreciable amounts of iron and manganese oxides with traces of silica and alumina. In preparing the high carbon alloy samples, this low metalloid iron mixed with powdered carbon was melted in a crucible, held a temperature of 1,500° to 1,550° C. for 20 mins., and then cast in a chilled mould. The carbon content of the iron-carbon alloy obtained varied from 4·6 to 6·0%. The manganese, silicon, phosphorus, sulphur and different combinations of these alloys were made by adding the appropriate ferro alloy in the desired amount to the iron-carbon alloy after remelting and removing slag. Four samples of each alloy with varying manganese, silicon, sulphur and phosphorus contents were cast in chill moulds. The preparation of the chilled samples for extraction of the oxides required considerable care, as they were very hard and brittle. The surface had to be cleaned by surface grinding, and when all the scale had been removed samples 1 in. wide and 4 in. long were cut in an abrasive cutting-off wheel, whereby some samples were so strained that they broke into several pieces, which provided the sample for oxide analysis.

The results obtained for the oxides in the low metalloid iron showed that they were in good agreement with those expected from theoretical calculations, with the exception of the MnO, some of which was eliminated during ingot solidification, as well as there being some slight solubility during extraction and washing. The S_1O_2 was low in this iron, averaging 0·0013%, and there was 0·0039% of Al_2O_3 from the aluminium added to the ingot during teeming. In the iron-carbon alloys prepared from the Armco iron, the addition of carbon reduced the FeO from 0·1653 to 0·0077%, and the iron-carbon sulphur alloys also had a low FeO content of 0·0072%. The iron-carbon-silicon alloys averaged 0·0048% FeO, and the iron carbon-manganese and iron-carbon phosphorus alloys 0·0039 and 0·0018% of FeO respectively. The addition of phosphorus also caused a general reduction in the total oxides, believed to be due to the reduced viscosity of the iron, as when the molten metal was held after the ferrophosphorus additions the molten slag was seen to come to the surface and to appear as a dirty yellowish-white opaque glass on cooling.

As a result of the determinations carried out on the various high alloy irons and also on different commercial grades of pig iron, it was shown that the electrolytic iron method of extracting oxide is applicable to cast iron as well as to steel, and that comparative and accurate results are obtained. The extraction apparatus is inexpensive, and although the method required considerable time, a number of determinations were made simultaneously. The oxide residue permitted isolation of the oxides for microscopic study and also for their complete chemical analyses. The investigation also demonstrated that metalloids do not cause high results or wide variations, and that different rates of cooling do not cause any difficulty.

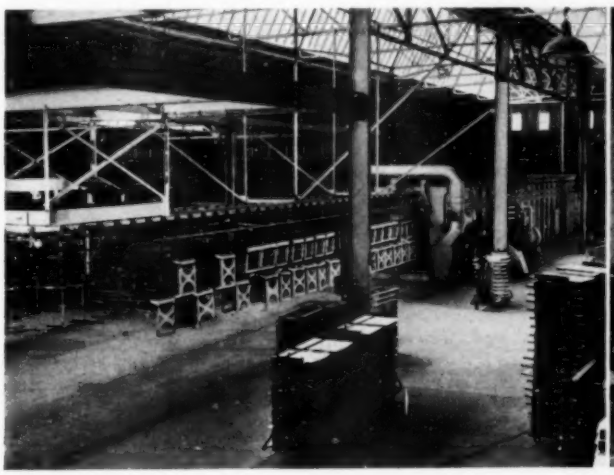
Metals and Alloys, 1938, Vol. 9, No. 7, pp. 171-174, and No. 8, pp. 201-206.

Recent Developments in Materials, Tools and Equipment

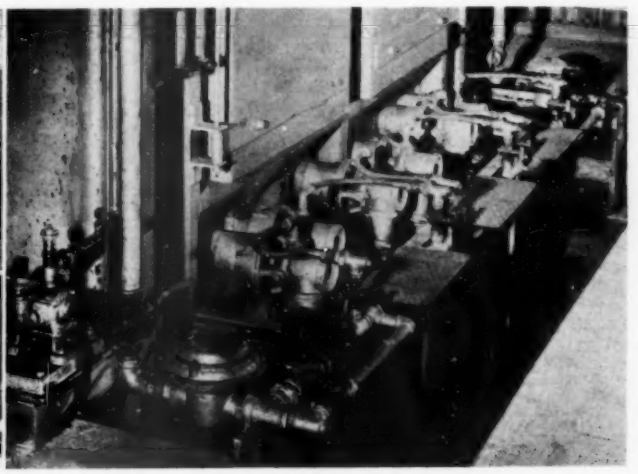
Gas-fired Continuous Enamelling Furnace

CONSIDERABLE interest is attached to a continuous enamelling furnace recently erected in the Falkirk Works of Messrs. R. and A. Main, Ltd. Designed by the Ferro Enamelling Company, it is fired by town gas and is claimed to be the only one of its kind in Europe. This furnace has an overall length of 140 ft., which includes a drying and preheat zone of 60 ft. and a fusing zone of 40 ft. It is fired by six diffusion-type burners, centred in the ends of radiant tubes, and each capable of delivering nearly 2,000 cub. ft. of gas per hour, a gas booster being used to raise the pressure up to 12 oz. The articles to be fused are carried through the furnace on alloy hooks attached to the continuous overhead conveyer, and this latter extends in front of the furnace for the purpose of loading and unloading, being driven by one 2-h.p. motor. Inside the furnace are six radiant tubes of chrome-nickel alloy designed to carry the gas flame through the fusing zone three times before passing to the preheat and drying chambers, whence, by means of calorised, and finally, steel tubing, it is exhausted to the atmosphere at only 200° F. tubes overcomes the difficulties that most enamellers find when a leak occurs in a gas-fired muffle, and the products of combustion escape into the furnace, spoiling the enamelled products. If a break should occur, the furnace gases are drawn into the tube rather than the products of combustion escaping into the furnace.

The time of the articles in the furnace is governed by the conveyer chain speed, and will vary from 2 ft. per min. on cast iron for enamelling, to 10 ft. per min. on sheet steel. Automatically controlled pyrometers govern the temperature at all points in the fusing zone, and by suitable manipulation this latter can be adjusted in length to suit the loading of the thin articles. Sheet iron, chain speed of 10 ft., is given a short firing zone, so that the speed must be decreased to ensure that the proper time is given for fusing, and thus enabling more work to be loaded per perritt in the time available. On cast iron, which is easily loaded at its slow and uneconomical chain speed of 2 ft., the reverse happens ; the firing zone is lengthened, and the chain speed can then be increased in proportion, enabling a larger production figure to be reached.



General view of furnace with overhead conveyer



The arrangement of the six diffusion-type burners.

This method has a big bearing on the furnace efficiency, and not only is all possible heat extracted from the waste gases, both in the furnace and in the preheat chambers, but the radiant tubes, being inside the firebrick lining, only need be maintained at a slightly higher temperature than the furnace itself, unlike the muffle or box-type of furnace, where the heat has to pass through firebrick or carborundum and consequently has to be at a considerably higher initial temperature. Additional saving is obtained by the fused or outgoing article giving up its heat when passing the incoming one in the preheat chamber, and a system of ducting is employed at the entrance and exit of the furnace which arrests any warm air trying to escape into the atmosphere, and recirculates it again to the preheat chamber.

The flame produced in the radiant tubes is supported by a stabiliser pilot arrangement, using premixed gas and air, and at the discharge end of the tubes are exhauster fans of 7½ h.p. each, which suck in the primary air at the burners, and tend to prolong the flame length in the fusing zone ; by altering the suction, the quantity of heat generated can be controlled and balanced in each tube. This system of a reduction atmosphere in the radiant

Only approximate production figures can be given, as this varies considerably with the class of work for processing, but a few general figures are given below :—

PRODUCTION DATA.

—	Casting Weight per Hour.	Casting Total Ratio.	Gas Consumption per Hour.	Cub. Ft. Needed to Fire 1 lb.
Cast-iron Ground Coat—	Lb.			
Box Muffle	660	1·4 to 1	7·5 galls. Oil	
Continuous	3,400	5·5 to 1	5,800 cub. ft. Gas	1·7
Cast iron Cover Coat—				
Box Muffle	1,050	1·3 to 1	8·5 galls. Oil	
Continuous	4,800	3·4 to 1	7,800 cub. ft. Gas	1·6

—	Sq. Ft. per Hour.	Total Weight per Hour.	Gas Consumption per Hour.	Cub. Ft. Needed to Fire 1 sq. ft.
Sheet-iron Ground Coat—		Lb.		
Box Muffle	280	960	10 galls. Oil	
Continuous	900	620	7,000 cub. ft. Gas	8·0
Sheet-iron Cover Coat—				
Box Muffle	350	450	7·5 galls. Oil	
Continuous	1,000	1,600	6,400 cub. ft. Gas	4·0

Cast iron shows a general saving against the box muffle type, both in the increased quantity of work which can be

loaded per hour, and also in the shorter fusing period necessary, the latter being due to the fact that the metal enters the fusing zone from the preheat at a temperature such as to require very little extra heat for fusing. The sheet-iron fusing period does not vary, the metal being only $\frac{1}{32}$ in. thick, which enables quick heating in any furnace with or without a preheat area. Production figures are improved, however, by the increased number of plates which can be loaded per perritt and consequently per hour.

A superior quality of work also is produced, the articles being uniformly heated up and cooled down, free from the troubles of perritt scale and perritt marks of the box muffles; more detailed and direct supervision is possible, all work for fusing passing through the one furnace, thus obviating the irregularities and differences of a battery of box muffles, and producing an improved and standardised finish on all work, to the betterment of the consumer.

A New Cement Sand Preparation Plant

THE application of the "Randeepson" cement sand process in the production of moulds involves considerable alterations and modifications to the usual processes of ordinary loam moulding, not the least of which is the care with which the cement sand itself should be prepared, mixed and used. In this connection considerable interest is attached to a cement-sand preparation plant recently installed at the Millwall works of the Manganese Bronze and Brass Co., Ltd., who are, we believe, the pioneers in the substitution of this process for the manufacture, in loam moulds, of their manganese bronze propellers for naval and mercantile vessels.

The preparation of the cement sand for use by this process is so important that special equipment had to be designed and installed in order that the broken moulds should be properly treated to ensure that the used cement when recovered would be properly graded for re-use. To meet the special needs, the plant installed has been designed and built by August's, Ltd. It has a capacity for receiving 8 tons per hour of used cement moulds and an output capacity of freshly prepared and mixed cement sand of 12 tons per hour. Reference to the diagrammatic illustration Fig. 1 shows the process involved.

The used foundry sand in the form of roughly broken moulds is dumped by crane tub on to the elevated platform shown on the extreme left. This platform will carry 40 tons of material. The used sand is shovelled by hand through the grid, in the floor of the platform, leading directly into the crushing mechanism, where the old cement sand is reduced to its original grain size. Falling through the crushing mechanism, the now crushed sand is collected on a conveyer belt and after passing through magnetic influence to remove any tramp iron, the crushed product is elevated directly on to a special type of screen.

In the screen the crushed product is graded into three groups—firstly, the oversize, which is returned directly from the screen back to the crushing mechanism; secondly, into the usable product itself (that is, sand of the requisite grain size); and thirdly, the silt, or refuse, which is sand of too fine a grain size to be re-used, and also, of course, such cement dust as still exists in the old sand. This silt or refuse is delivered from the screen directly into a small hopper through which it is loaded into bags ready for discard.

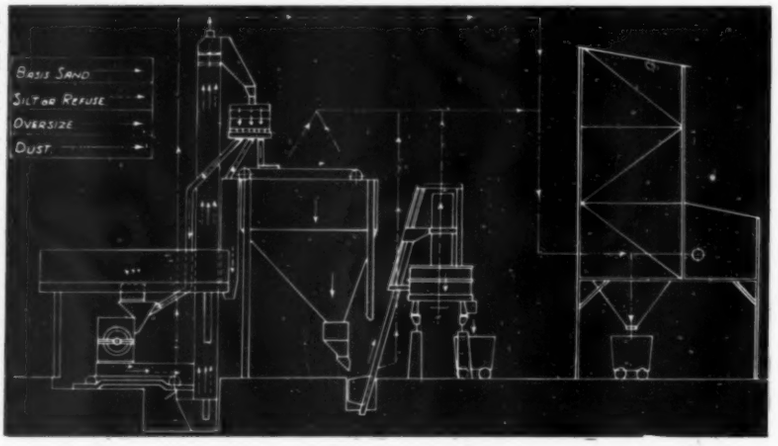
The basis sand, or sand that is to be re-used, is collected from the screen and distributed by means of a conveyer, evenly into a large basis sand-storage hopper with a capacity of 80 tons.

From the base of this sand-storage hopper the requisite quantity of basis sand is drawn off into a single bucket loader feeding either one of two mixing units. Added to the charge of basis sand in the bucket loader is the requisite amount of new sand and cement, and the whole of this charge then elevated and fed into one of the two mixing machines.

The correct amount of water, registered by meter, is added during the mixing in the machines, and after a requisite mixing time the door in the floor of the pan of the machine is opened, permitting the mixed cement sand to be discharged into wheel tubs for distribution to the moulders.

Owing to site conditions, the design and construction of the plant presented many difficulties, but after having been in operation for three months the plant is proving very satisfactory, and has, indeed, exceeded the original expectations.

The propeller and other castings produced by this new process are extremely accurate, and the grain size of the cast bronze is finer and more uniform, ensuring longer life, and improving the corrosion and erosion-resisting properties of the material. Further noteworthy results are the increased floor space available, and the generally improved working conditions in the foundry.



A diagrammatic view of the cement sand preparation plant showing the flow of the various products.

The accompanying illustration shows not only the arrangement of the plant, but the flow of the various products through the plant. It will be noticed particularly that the dust problem is under complete control. With cement-sand preparation plant this is indeed a vital factor, and the whole of this particular plant is provided with a most elaborate dust collection system. The structure shown on the extreme right of Fig. 1 is the dust collection unit, and shows the size of this unit proportional to the size of the rest of the plant. Every point in the plant at which dust is likely to be created is carefully hooded, and the dust sucked from that point to the main dust-collecting system. Some idea of the provision for dust will be gathered when it is realised that the fan on the dust collection exhaust system is operated by a 20 h.p. motor.

Fourth Blast-furnace at Azovstal

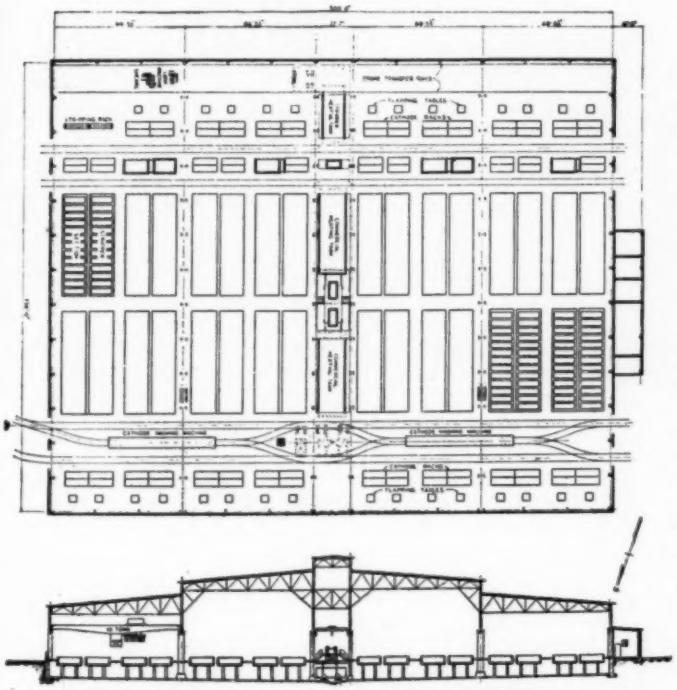
A message from Mariupol says that the building has been commenced of the fourth blast-furnace at the "Azovstal" Metallurgical Combine in the Ukraine (near the Azov Sea). The new furnace will have a useful volume of 1,300 cubic metres, and be capable of producing 1,500 tons of pig-iron per day. In type it is similar to the third blast-furnace of this plant, which is practically completed. With the starting of the fourth blast furnace, the "Azovstal" Combine will be able to turn out 5,000 tons of pig-iron per day.

The Nkana Copper Refinery

By A. E. Wheeler and H. Y. Eagle

A modern electrolytic and furnace refinery is in operation at the Nkana plant of the Rhokana Corporation, Ltd., in Northern Rhodesia, which converts part of its blister copper output. The installation was described by the authors at the recent Rochester meeting of the Electrochemical Society, the main features of which are embodied in this article.

THE first electrolytic copper refinery to be built on the African continent is in operation at the Nkana plant of the Rhokana Corporation, Ltd., in Northern Rhodesia. Although electrolytic copper has been produced in Africa from the leaching operations of the Union Miniere du Haut Katanga in the Belgian Congo since 1922, the copper is a primary product by electrolysis from leaching solutions, whereas the Nkana project involves the conversion by electrolysis of blister copper into refined copper output, thus it can be claimed to be the first of this character to be installed in Africa.



Plan and elevation of the electrolytic tank-house, showing the starting sheet and the commercial tanks.

The Nkana blister copper is of exceptional purity, and its precious metal content is too low to justify electrolytic refining simply as a means to recover these values. Although the total of all impurities is notably small, there is present a relatively large amount of the objectionable element bismuth, which precludes the conversion by Nkana into the higher grade of copper by fire-refining methods only. Extensive experimental work by the Corporation and other investigators failed to develop a satisfactory method of eliminating the bismuth during the smelting operations, and electrolytic refining seemed to offer the only effective means of lowering the content of this impurity to values entirely satisfactory to consumers.

The question of refining its own copper had been under consideration by the Corporation for several years, two different studies having been instituted to develop the economics of the idea. The first of these covered the possibilities of a refinery to be located in England, and, later, a similar study was made for a refinery to be located at the Nkana smelter in Northern Rhodesia. The latter location proved to be very much the more attractive, but the large excess of refining capacity in the United States made favourable refining contracts there possible, and, for a long time, the Rhokana copper was refined in the United States on a custom basis. With the departure from the gold standard, however, such contracts became highly speculative, and the situation was further complicated by a tariff placed on imported copper by the United States. As a result of these economic developments, it was decided to proceed with the construction of a refinery in Africa.

Theory of Electrolytic Refining

The theory of electrolytic refining is simple. If in an electrolyte of suitable composition are placed two copper sheets connected to the terminals of a generator, the sheet connected with the negative pole being known as the cathode, the other connected with the positive pole being known as the anode, on passing a direct current of suitable voltage and density, the current will enter the anode, passing through the solution to the cathode, dissolving copper from the anode and depositing an equivalent quantity of copper upon the cathode. Owing to the energy generated at the anode by the solution of the copper, the total intensity factor, the voltage, is small, usually about 0·25 volts per tank at a normal current density of 16 amperes per sq. ft. The capacity factor, the amperage, follows strictly Faraday's law, copper acting as a divalent metal, 1 ampere per hour depositing 1·186 grms. of copper.

In practice, a number of tanks are connected in series with the electrodes in the individual tanks being in multiple. The electrolyte is an acid solution of copper-sulphate, usually 45 grms. per litre of copper, with 200 grms. per litre of free sulphuric acid. The current dissolves the impure copper from the anodes and deposits pure copper on the cathodes, the impurities either dissolving and fouling the electrolyte, or not dissolving and dropping to the bottom of the tanks as slime.

The New Refinery

The new refinery consists essentially of an anode department, making anodes of refined blister copper ; an electrolytic tank-house, which converts the anodes into cathodes by electrodeposition ; and a furnace refinery, in which the cathodes are melted and cast into commercial shapes. Necessary installations, auxiliary to these, are the electric sub-station, slimes treatment plant, steam boiler plant, and the industrial railway system providing interdepartmental transport. The rated capacity of the refinery, as built, is 36,500 short tons of refined copper output per year, but provision has been made in its layout to permit future extension up to five times its present capacity.

Anode Department

The anode department occupies an extension of the converter and casting aisles of the Nkana smelter, and takes molten blister copper delivered from ladles directly into the refining furnace. The anode furnace is of the cylindrical tilting type, 13 ft. diameter and 30 ft. long, lined with magnesite brick and fired with pulverised fuel. It is operated on a 24-hour cycle. the usual oxidation and reduction steps being carried out to yield anode copper of proper set and composition. The refined copper is poured

from the furnace directly into an hydraulically operated pouring spoon, which delivers it to the casting machine.

The casting machine is a Walker wheel, 24 ft. in diameter, which carries 14 cast-copper anode moulds, each provided with a single push-pin for extracting the anode from the mould. At a location approximately opposite the pouring point, the push-pins are actuated by an air cylinder, and the anodes are lifted sufficiently at one end to permit them to be picked up by the bail of the Whiting anode-bosh crane. Proper regulation of mould temperature is effected by a series of adjustable water sprays located both above and below the moulds. A removable insert block on each mould provides for casting the cathode-bar groove in one of the lugs. These insert blocks are replaced after the anodes are removed from the moulds, which, after being sprayed with a pulverised silica mould wash, are again ready for pouring. Anodes are poured carefully to a definite depth mark, a variation of ± 5% from the desired weight being sufficient for anode rejection. Two different types of anodes are produced: standard anodes used for cathode production weighing 625 lb. each, and stripper anodes used for starting sheet production weighing 700 lb. each.

Electrolytic Tank-house

The tank-house is arranged with a main operating floor and basement, and has four tank aisles and a central pump aisle. It contains 416 electrolytic tanks, 26 of which are devoted to starting sheet production and the remainder to cathode production. The tanks are built up in nests of 13 tanks each of pre-cast concrete slabs, and are lined with 6% antimonial sheet lead $\frac{1}{8}$ in. thick. They are supported on concrete piers which are topped with glass-block insulators and are protected from possible solution leakage by sheet-lead drip-pans. Each tank is provided with facilities for the discharge of the silver slimes into the launder system in the basement. Solution enters the tank at the top at one end and leaves near the bottom at the other end. Anodes and cathodes are each spaced on 4$\frac{3}{4}$ in. centres, the starting sheet tanks containing 29 stripper anodes and 28 starting sheet blanks, and the commercial tanks 32 anodes and 33 cathodes.

The tanks are arranged on the multiple system, with the tanks in series and the electrodes in parallel. All 416 tanks are in series in a single electric circuit and operate normally at a current density of 14 amp./sq. ft. of cathode surface in the commercial tanks and 16 amp/sq. ft. in the starting sheet tanks. The cathode bars of one tank engage the grooves in the lugs of the anodes in the next tank, thus cutting down the number of contacts to a minimum. Contacts are designed for minimum voltage drop and the layout for minimum conductor bar runs. The tanks may be easily cut out of circuit in groups of 26 tanks by a suitable jumper bar and clamps. When operating at a normal current supply of 8,750 amperes with six insoluble anode tanks in service, the total voltage drop for the circuit at the sub-station switchboard is 65 to 70 volts. A natural result of the low electrical resistance of the circuit is a high energy efficiency, more than 300 lb. of cathode copper per kilowatt day having been produced by a "green" crew during the starting-up operations.

Electrolyte is circulated through the tanks at the rate of 4 imp. gals. per min. per tank, and its temperature is maintained at approximately 56° C. by means of steam coil heaters. Two return vacuum pumps, one of which is a spare, take the condensate from the solution heaters and deliver it into the condensate storage tank, from which it is drawn for solution make-up. There are three separate solution-circulating systems, one for the 26 starting sheet tanks, one for 182 commercial tanks, and one for 208 commercial tanks. Each circulation system has its own solution heater, head tank, and two (one spare) electrically driven pumps of the horizontal centrifugal type.

In general, the scheme of tank-house operations is as follows: Starting sheets are stripped from the 26 stripper tanks every 24 hours. The starting sheet blanks are removed from the tanks by the crane on multi-hook bails in half-tank lots without interrupting the current. The blanks are stripped on vertical racks and, after being greased with a light gas oil, are returned to the tanks. Part of the resulting sheets are cut up on a squaring shear to form loops, which are riveted to the other sheets on a clip machine to form the starting sheet cathodes. These cathodes are flapped on wooden tables and suspended from clean cathode bars in steel racks in which the longitudinal and lateral spacings of the bars and sheets are definitely fixed to correspond to their proper use in the electrolytic tanks.

On each weekday 26 tanks of finished cathodes are drawn, their age being 18 days for the first three drawings and 17 days for the last three drawings of the week. They are removed from the tank, and after draining are deposited in the cathode washing machine. The cathodes are here sprayed first with hot acid solution, then with fresh water, and finally deposited on cathode cars in piles suitable for handling by the charging crane in the furnace refinery. As the cathodes are being loaded on cars the cathode bars are removed from the loops and placed in copper pickling baskets. These, after immersion overnight in hot acid solution in pickling tanks, are removed, washed with water, and are ready for use by the sheet flapping gang.

After the cathodes have been drawn, the anodes of the 13 tanks, which have been corroded for 35 days, are drawn as scrap. This scrap, after washing, is sorted, light scrap being loaded on cars to be returned to the smelter for remelting, and heavy scrap being stored in anode scrap racks for scrap-juggling purposes. The solution in the 13 tanks from which anodes have been removed is dropped to the 8 in. (20·3 cm.) depth by pulling the end plug, and then the bottom plug is pulled delivering the slimes into the launder system, which discharges them into the slimes sump through a fine-mesh Monel screen. From here it is pumped to the slimes plant for further treatment.

In order to maintain the electrical efficiency of the system, a comprehensive system of inspection is maintained to detect and correct any short circuits or bad contacts which may develop and to replace any scrap which may become too light to support itself before its maturity date. To maintain the purity of the electrolyte, a portion is regularly stripped of copper in insoluble anode tanks, concentrated by evaporation, impurities removed by crystallisation and the restored acid returned to the circuit.

The Furnace Refinery

The furnace refinery is a steel frame structure, 144 ft. long by 181 ft. 6 in. wide, with concrete floors, sheathed with brick and galvanised corrugated iron, and roofed with asbestos felt laid on wood decking. The building is arranged with its operating floor on two levels and has three crane aisles and a furnace aisle. The charging aisle is equipped with a 7,000-lb. Wellman Smith Owen cathode charger and a 5-ton Vaughan general service crane. The casting and inspection aisles are each equipped with a 10-ton Vaughan general service crane. The refining furnace is of the stationary reverberatory type, with a hearth 40 ft. 8$\frac{1}{2}$ in. long by 14 ft. 3 in. wide, and a metal capacity of 200 to 250 tons. It has a sprung arch roof and an inverted arch bottom, both of silica brick construction. The side walls are of magnesite and silica brick, the former being carried to above slag line. The firing end of the furnace is provided with a proper combustion chamber for pulverised coal-firing through a single burner, and natural draught is provided by a brick-lined steel stack. A line of nickel-chromium steel heat-exchanger tubes, supplied with air from the primary air fan, provides hot air for drying the coal in the unit pulverisers.

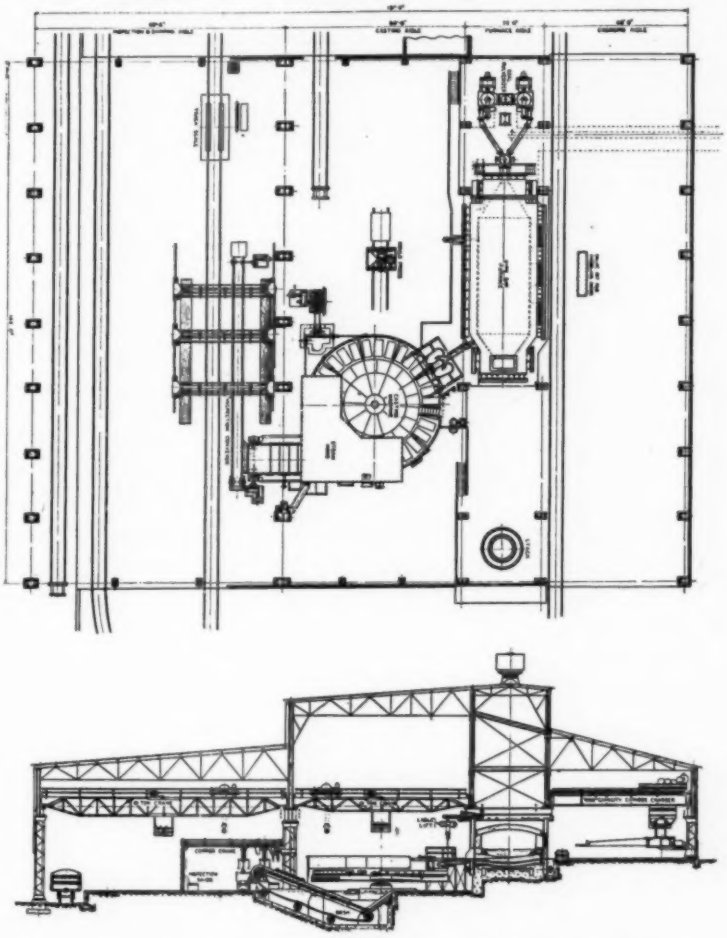
The casting equipment consists of two electrically tilted ladles, a 38-ft. diameter Clarke-type casting wheel, together with the necessary bosh, bosh conveyer, inspection conveyer, and auxiliary handling equipment. The casting wheel is provided with roller bearings throughout and is

electrically driven through spur-gear reductions and an endless rope drive equipped with gravity take-ups for movement in both directions. It is designed to accommodate 30 three-pocket wire bar moulds, 20 ten-pocket ingot bar moulds, or the equivalent of these in any other shapes, and is suited to the production of most of the shapes demanded by the trade. The moulds are attached by clamps to forged-steel trunnions supported on the wheel by cast-steel bearings, which are designed with simple means for setting the moulds dead level in both directions. At proper points in the revolution, suitable devices are provided for discharging the moulds. An accurate control of mould temperature is effected by a series of adjustable water sprays located both above and below the moulds.

The furnace refinery of the initial Nkana installation has a capacity of at least double the daily tank-house production, so that the furnace is operated for only about one-half the time. The tank-house output is stored when the furnace is down, and, when it is operating, cathodes are drawn from both storage and the daily tank-house production.

The furnace is charged through three side doors by the cathode charging machine, and when it has been piled full of copper the doors are closed and luted and melting down is started. Vigorous firing is maintained until the charge is all melted and has come off the bottom, at which time the bath is skimmed clean and air pipes are inserted through the openings in the side doors. Oxidation of the charge is continued by blowing and flapping until the oxygen content of the bath has risen to about 0·90%, any resulting slag being skimmed off as it forms. When this point is reached, the fracture of an assay ladle button shows a characteristic coarse block grain, and the oxidation is stopped. The bath is skimmed clean, covered with a protective layer of low sulphur coke, and reducing operations are started. Reduction is effected by the insertion into the bath of green poles of native hardwood cut locally, and is continued until the oxygen content of the bath is reduced to about 0·03 to 0·04%. At this point, a small block sample cast with a hand ladle shows the characteristic tough-pitch set and the absence of a "spot," and the charge is ready for casting. During the casting operation, the set is watched closely and is maintained at the desired point by careful temperature and draught control, and the occasional introduction of a green pole when necessary.

The molten copper is tapped from the furnace and delivered by launder to the two ladles. The wheel is rotated until two moulds line up with the ladles and the operation is repeated. As the wheel progresses slowly in its revolution, the moulds are successively sprayed, dumped, painted with bone ash mould wash and returned to the ladles for repouring. The finished shapes quenched and delivered to a conveyer are subjected to a rigid inspection for physical defects. Three bars from each charge, one each from beginning, middle, and end of the cast, are drilled for samples and assayed for copper, oxygen, and sulphur. Three small bar samples are similarly taken from the furnace from each charge for conductivity determinations. These are swaged down to ¼ in. diameter rod, then drawn to No. 12 B and S wire, and conductivities are determined on both the hard-drawn and annealed samples. Every effort is made to insure that only copper which entirely meets required chemical and physical specifications is shipped.



Section

Plan and sectional elevation of the furnace refinery, showing the reverberatory furnace and the Clarke-type casting wheel.

New Copper Brand

The building of the Nkana refinery necessitated the establishment of a new copper brand, as Nkana copper had previously been marketed under the brands of the various custom refineries which handled it. The new brand for Rhokana copper was registered on the London Metal Exchange as REC, and, to establish the brand, initial lots of wire bars were sent to three different fabricators in England to investigate its quality. Comprehensive rolling and wire-drawing tests were carried out on this copper in competition with established brands and demonstrated it to be a satisfactory competitive produce in every respect. Rhokana electrolytic copper, under the REC brand, has been exceptionally well received by the trade.

It is noteworthy that more than 90% of the total cost of this plant was expended within the British Empire. Structural steel-work, electrical equipment, cranes, heavy machinery, antimonial sheet lead, and miscellaneous supplies came from Great Britain; timber from British Columbia; pig lead from Australia; silica brick from India; miscellaneous equipment from the Union of South Africa; while the Rhodesias furnished cement, sand, stone, brick, lime, sulphuric acid, and other local products.

Head, Wrightson and Company Limited of Thornaby-on-Tees, have obtained a contract from the Malay States for the supply of manganese steel spares for dredgers in the tin producing districts. These castings, which must withstand the most abusive conditions, are to be produced in a special grade steel at Thornaby-on-Tees.

Technical Advances in Mining and Low Grade Ores

THE mining industry in the United States has long since skimmed the "cream" of most of the rich mineral deposits, and is now faced with the problem of working grades of ore which a generation ago would have been considered worthless. The ingenuity and inventiveness demanded by this decline in ore grades has brought about great improvement in mining technique. In spite of decreasing metal content per ton of ore, technical progress has produced a rising output per worker for all major metals. These facts are brought out in a recent report prepared by the Works Progress Administration National Research Project in co-operation with the U. S. Bureau of Mines. Under the title, "Mineral Technology and Output per Man Studies: Grade of Ore," it analyses the effect of lowered ore yields in such minerals as gold, silver, copper, lead and zinc.

Despite improvements in technique, however, there comes a time in the life of every mine when the yield of valuable content per ton of ore continuously fails to return a profit; the mine then ceases to be an employer of labour and leaves in its wake the half-abandoned camps that are found in many of the older mining districts. Some of the effects of this depletion are found in the heavy relief rolls of many western mining areas, where early vigour has waned, in the changing geographical distribution of employment opportunities for mine workers as mining shifts to new localities, and in the modified skills required by "mass mining" of low-grade deposits with new varieties of equipment. Also, when adverse economic conditions force reduced production, employment is sharply affected as efforts are made to raise the yield by the selective mining of small tonnages of high-grade ore. For example, the report points out that Michigan copper mines reduced their output of ore by 68% between 1931 and 1932, and raised the yield by 45% by means of selective mining. This did not greatly change the output of copper per man, but it resulted in sharp changes in employment, since the man-hours worked underground were cut 72%.

The study goes into the subject of the general decline of ore grades, prefaced by a brief description of early "bonanza" mining when a pick and shovel were the principal items of equipment, and discusses the technical advances which have made possible the profitable working of low-grade ores. Separate chapters are devoted to gold and silver ores, copper, and lead and zinc, while in a final chapter on output per man, it is pointed out that approximately one-half the nation's present copper supply comes from mines which were known but considered worthless in 1900; that silver and gold deposits with one-tenth the yield required for profitable production 50 years ago are being successfully worked to-day, and that in spite of a 27% decline in ore yields in lead mines in the last quarter of a century, such deposits are still being worked at a profit. Metal mining, the report states, has had to adjust itself to a lower grade of ore, and the success of this process has been one of the important victories of mineral technology. This report consists of 114 pages, including an appendix of numerous charts and supplemental material. It was prepared by Andrew V. Corry and O. E. Kiessling.

Expeditions of the Academy of Sciences

THE Academy of Sciences of the U.S.S.R. is sending out three big complex expeditions in 1939, one to the European plain of the Union, another to the Caucasus, and a third to the Urals. The aim of the expeditions will be to study the mineral, agricultural, water and power resources of the regions in question. The work of the expedition to the Urals will deal mainly with the industry of the Urals in relation to the needs of its principal branches, ferrous, quality and non-ferrous metallurgy and the allied industry of machine building. The expedition will pay special attention to prospecting for rare metals.

Catalogues and Other Publications

The development of the grid scheme in this country has called for large size hollow-forged boiler drums and receivers capable of withstanding high pressures and temperatures, and the establishment of hydrogenation plant has also demanded high-pressure vessels. Having expended nearly £3,000,000 on reconstruction and modernisation of its plant, the English Steel Corporation is able to supply such forgings, among a wide variety of other products. These are outlined in their new 24-page booklet, entitled "E. S. C. and Its Products," printed in two colours and well illustrated.

In those pages it is shown how cast ingots up to 250 ton weight, in carbon and alloy steels, can be produced; these steels, including case-hardening steels, carbon and special steels for all purposes, manganese molybdenum steels, high tensile alloy steels, nitriding and magnet steels. The various productions of the Corporation, in the form of castings, forgings, pressings, and drop-forgings are also mentioned, together with the products of their rolling mills, precision-ground bars, cold-drawn and centreless bars, many varieties of springs, files and hacksaws, tool steels, magnets, and small tools.

A 27-page book issued by I. C. I., Ltd., gives a summary of the industrial applications for ethylene glycol, with particular reference to its use as an anti-freeze agent in water-cooling systems. Although it was once a fairly expensive chemical, ethylene glycol is now available in bulk at prices which enable its advantages to be used in many applications. This book details the five specific grades in which the I. C. I. market ethylene glycol, together with their particular qualities. One grade, for instance, is applicable to aero engines as a high-temperature coolant, and another has a chloride content of less than 0·0001%, thus making it specially appropriate as a dielectric in electrolytic condensers.

Such other uses as the function of a hygroscopic agent, a plasticiser, and a basic solvent for inks, are described; and the book is complete with graphs showing the freezing points of a range of aqueous glycol solutions, densities, boiling points, and tables giving the amounts to use at various winter temperatures in cooling systems. Useful handling hints are also included.

The sixth edition of the catalogue of Adam Hilger, Ltd. London, for outfits for absorption spectrophotometry, is well described as a guide to the choice of suitable spectrophotometric apparatus for work in both the ultra-violet and the visible regions. In the former case, outfits applicable to the study of the relation between absorption and chemical constitution, the dissociation constants of inorganic and organic compounds, and the effect of solvents on absorption spectra, for the measurement and identification of organic substances, are described. In regard to work in the visible region, the outfits described and illustrated include those suitable for identification and measurement of dyes, natural or artificial colouring matters of substances, and similar applications, by photographic, visual and photo-electric methods. There are very useful notes on the selection of specific equipment. Illustrations, charts and notes add to the value of this comprehensive, priced catalogue.

The companion catalogue, for spectrographic outfits for metallurgical and general chemical analyses, is equally valuable, acting as a guide to the choice of equipment suitable for technical laboratories, this being the ninth edition. A good spectrograph with modern accessories enables the whole of the metallic constituents of any metals or alloys, and of mineralogical preparations, to be detected accurately and quickly. The chapter on the choice of equipment for metallurgical work is one which we can commend. Details, illustrations and prices are also given of five other methods of quantitative spectrographic analysis, these being the stepped sector method, logarithmic sector, Barratt's twin spark, the ratio quantitative method and the Ramage flame method. Copies from Adam Hilger, Ltd., 98, King's Road, Camden Road, London, N.W. 1.

Personal

Mr. C. W. Chapman, technical director of F. Perkins, Ltd., of Peterborough, has been awarded the Derby Gold Medal for the 1937–38 Session of Lectures by the Liverpool Engineering Society. His paper was entitled "High-speed Diesel Engines," and was read before the Liverpool Engineering Society on November 3, 1937.

Business Notes and News

Steel Output Higher

The September output of steel ingots and castings of 754,700 tons represents an advance of 15% on the August production, and although the actual working days in September are greater as compared with August, the increased production is such that it indicates greater activity in the industry as a whole and the first expansion since May last. The fact that at the end of September there were 28 more open-hearth furnaces in operation compared with a month earlier, and four more compared with the close of June, seems to confirm an expansion in the industry. However, the steel output reached is about 35% below the figure for September of last year, when the output was 1,163,000 tons. Pig-iron production fell slightly to 429,800 tons in September, as compared with August, but since the former month contained one working day less, the daily average shows little change. Again, the production is much less than in September of last year. Seventy-seven furnaces were in blast at the end of the month, compared with 81 furnaces at the end of August, seven furnaces having ceased operations during the month and three being put into production.

New Rolling Mill Plant for Banbury Works

The Northern Aluminium Co. has recently placed orders for considerable extensions to their Banbury works, the principal item of new equipment being a complete hot reversing rolling mill, the order for which has been placed with the Brightside Foundry and Engineering Co., Ltd. At the same works a large number of sheet mill finishing stands, complete with gear drive, have also been installed recently. In addition to the rolling mill equipment, the whole of the furnace equipment and general accessories being ordered in connection with the Company's present extensions are to be of British manufacture.

Burdon Furnaces New Company

Burdon Furnace Co., Scottish Industrial Estate, Hillington, Glasgow, S.W. 2, designers and manufacturers of gas, oil and solid fuel-fired industrial furnaces, have recently formed a separate company—Burdon Electric Furnace Co.—for the the manufacture of electric-heated industrial furnaces. We understand this new company has obtained the sole manufacturing rights for Great Britain and the Dominions for the electric furnaces designs of Messrs. F. Ferre and Co., Milan.

Iron and Steel Institute

Prizes and Grants to be Awarded

The Council of the Iron and Steel Institute have accepted an offer from Captain C. A. Ablett, O.B.E., B.Sc., M.Inst.C.E., to present a prize of £50 for the best paper on Steelworks Engineering submitted to the Institute, written by a junior engineer employed in a British iron and steel works, irrespective of whether or not he is a member of the Institute. Competing papers should be marked "Ablett Prize Paper," and sent to the Secretary of the Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W. 1, not later than January 31, 1939.

The Williams Prize to the value of £100 is presented annually, subject to the discretion of the Council, to the author of a paper of a practical character adjudged by them to be the best paper of that character presented to the Institute and accepted for publication at the Annual or Autumn Meeting each year. The author of the paper must be a British subject, regularly employed in a British iron and steel works, and at the time of presenting the paper be employed in such works in a position not superior to that of manager of any one technical department.

In addition, Andrew Carnegie Scholarships, usually to the value of £50 or £100, are awarded annually in order to assist those engaged in research, irrespective of sex or nationality. Candidates must be under 35 years of age and applications should be made on forms, obtainable from the Secretary of the Institute, and should be submitted not later than September 30 in each year.

Increased Production of Copper

The copper-producing companies in the control scheme have decided to advance their output from 95% to 105% of the agreed basic tonnages from October 15, according to an official announcement. In the main, this announcement affects seven large producing companies: Rhokana, Roan Antelope and Mufulira, in Rhodesia; the Chile Copper Co.; Andes Copper Co., and Braden Copper Co., in Chile; and the Union Miniere du Haut Katanga, in Belgian Congo.

The control agreement began in 1935 with a quota of 70%, which was successively increased to 105% late in 1936, when restriction was suspended because of the rising trend of prices. Prices, however, continued to boom until the spring of last year, when they broke abruptly. Control was reimposed at the end of last year on the basis of 105% of standard tonnages, and in June last the quota was cut to 95% of standard.

The belief in a rising consumption trend is so firmly held that this announcement has done little to check the rising tendency of prices, and it is noteworthy that copper shares are in considerable demand.

Engineering and Shipbuilding Awards

The Council of the North-East Coast Institution of Engineers and Shipbuilders have made the following awards: The "Institution Gold Medals" for papers read during the session were awarded to Mr. G. J. Lugt, Prof.-Ing. F. Horn, and Dr. T. Swinden. The Thomas Fenwick Reed Gold Medal to Mr. John Hindmarsh, B.Sc., Wh.Sc.

The Institution is awarding two new scholarships this session, each valued at £100, to Harry Chilton, an apprentice of North Eastern Marine Engineering Co. (1938), Ltd., and a student of Sunderland Technical College; and Thomas Corin, an apprentice ship draughtsman in the employment of Messrs. Swan, Hunter and Wigham Richardson, Ltd. He will study at King's College, Newcastle-on-Tyne. Prizes of £5 each have been awarded to two other meritorious candidates for the scholarship—namely, Cecil Francis Croisdale and Ernest Young.

Concern in Shipbuilding Industry

Serious concern is being experienced in the mercantile shipbuilding industry by the lack of new orders. In the third quarter of the year new orders total only 30,000 tons, in comparison with 100,000 tons during the same period last year. Total orders for 1938 are not expected to exceed 300,000 tons, and the outlook is regarded as grave. It is expected that the Lloyds Register returns, which will shortly be published, will show a further decline in the total merchant tonnage under construction in British yards.

In the absence of revival in demand, it is feared that by the end of 1938 merchant tonnage under construction will have fallen to under 750,000 tons, and by the middle of 1939 to around 500,000 tons, or about a quarter of present berth capacity. The loss of export markets is largely the cause of the present poor showing of the industry. Work now on hand for foreign owners is valued at about £3,000,000, and against this must be set off about £6,500,000 of orders at present under construction in foreign yards for British owners. Under these conditions it is not surprising that shipbuilders are supporting a plea for a national shipping-shipbuilding policy.

Brush Electrical Engineering Works

Production at the works of Brush Electrical Engineering Co. for the Current year is greater than it has been for many years, and the prospects for the maintenance of a higher output are exceedingly good. Large orders for bus bodies have been received since June, and repeat orders for turbo-alternator plant and for Diesel engines and switchgear have also been received, it was disclosed. All departments of the works are well employed.

The Company recently acquired the old-established oil-engine business of Petters, Ltd., and the work of transferring manufacture from Yeovil to Loughborough is being rapidly pushed forward. New machine tools and plant to the value of £150,000 is being installed, and this immense operation will be completed within three months. Apart from the transplanting of Petters' business to Loughborough, however, large-scale extensions to the Brush works are being planned in order to accommodate the increased business in the Company's coachbuilding and electrical departments. The Brush works, which now cover some 36 acres, are being thoroughly reorganised and replanned.

The Official Participation of the United Kingdom in the New York World's Fair, 1939

FRIENDLY international rivalry will be promoted at the New York World's Fair of 1939, which is designed to show something of the advancement of human welfare, the creation of a better, easier and more abundant life. When this Fair opens in April next it will commemorate the 150th Anniversary of the inauguration of America's first President, and its theme will be " Building the World of To-morrow," and will cover past, present and future activity in science, arts, administration, industry, transportation, education, housing, etc.

Set in the very heart of Greater New York, the New York World's Fair will be the largest exhibition yet held in the world, covering an area of more than 1,200 acres, extending for a length of 3 miles and a width of 1½ miles. Waste land nearly four times the size of Hyde Park has been reclaimed for its site, £2,000,000 sewage disposal plant has been constructed, some 10,000 trees planted, and 15 miles of roads and avenues, 100 feet wide, built within the Fair grounds ; these are but a few indications of the large-scale preparations which are being made as a fitting setting for an exhibition which will undoubtedly set up new records in the history of international exhibitions.

The Fair will be truly international in spirit, and foreign participation will be unprecedented ; some sixty nations will be represented, most of them in their own pavilions. Of the major nations of the world, Germany, China and Spain alone will not be represented. The close and friendly relations which have so long existed between the United Kingdom and the United States make it no matter for surprise that the United Kingdom should be represented officially in this exhibition on a very large scale.

The United Kingdom and the United States are the two most important trading countries in the world. Together they transact over 25% of the total trade of the world, while if the rest of the British Empire is included, the proportion is over 40%. Again, the value of trade between the United Kingdom and the United States is greater than that between any other two countries in the world except the United States and Canada. The United Kingdom is the United States' best customer, whilst as a supplier to the United States this country is second only to Canada.

The Department of Overseas Trade is responsible for official United Kingdom participation in the Fair, and the planning of the various sections of the Government Pavilion. The Dominions of Canada and Eire will have their own pavilions ; the Dominions of Australia and New Zealand and the Colonial Empire will organise separate official exhibits with the United Kingdom in the British Pavilion. This Pavilion will occupy a dominating position at the end of Constitution Mall, the great central avenue of the Fair extending from the Trylon and Perisphere, which form the theme centre of the Fair, to the Lagoon of Nations.

The two areas provided for British participation are divided by a road, and both have curved frontages. But, as sometimes happens, the difficulties lead to individual possibilities of treatment. There is, for example, the necessity of an intersecting bridge to link the two main divisions, the Hall of Majesty, which is the grand vestibule to the United Kingdom exhibit, and the Hall of Achievement, which forms the bigger section overlooking an English garden. Then there is the access to the Hall of Majesty, which is on the bridge level—i.e., on the first floor. This gives rise to the monumental double outside staircase, mounting 18 ft. wide in an open loggia, and dominating the great oval lagoon, which is the Square of Honour, leading to the American Government buildings. This staircase will be approached under a gilded portcullis bearing the Royal Arms in colour. The wall backing the staircase will be fluted, and entirely gilded. Doors of bronze will lead to the two circular vestibules, which are the twin entries to the series of apartments forming the Hall of Majesty, the central one of which will be 180 ft. long and 75 ft. in width. The outstanding features of these apartments will be an exhibit of replicas of the Crown Jewels, a special exhibit of British coinage arranged by the Royal Mint, an exhibit of modern silverwork by the Goldsmiths' Company, and, in the central hall, an exhibit of pageantry will depict the history of England in terms of Heraldry. The exhibit here will recall vividly by means of coats-of-arms, banners and appurtenances many aspects of the traditional pageantry of Great Britain.

Passing from this central hall visitors will cross a 28-ft. bridge leading to the Hall of Achievement, and will see in front of them a floor descending in three easy stages, while at the same time the roof above them rises in three tiers to a height of 90 ft. at the far end of the building 300 ft. away.

At the end of the long vista thus afforded will stand a beautiful golden statue, 45 ft. high, which will be one of the biggest pieces of sculpture ever placed inside a building. The architectural treatment of the long nave leading up to that figure will be simple and severe, for the statue will be the climax of the architectural conception, while the exhibits within the central nave and its two aisles will be allowed to dominate in interest.

The Hall of Achievement will be daylight lit. A row of vast windows, shaded by triple-tiered awnings, will present an unobstructed view of the English garden, and a verandah terrace opening out from the ground floor will give shaded access to it. At one end there will be a bandstand for 60 musicians high above the garden, the whole space of which will thus be free for lawns and planting. The band of the Coldstream Guards will play there from the opening on April 30 onwards for a month, and in September the band of the First Battalion of the Argyll and Sutherland Highlanders.

In front of the great statue, inside the Hall of Achievement, a double staircase leading down to the ground floor will enable visitors to go back to the other entrance to the building, which is beneath the bridge connecting with the Hall of Majesty.

On the first floor of the Hall of Achievement special exhibits are being organised by the Ministry of Health, the Ministry of Labour, and the Board of Education in co-operation, depicting interesting aspects of the many and varied Social Services of the United Kingdom ; a Maritime Section illustrating the progress of sea transport, and a series of industrial exhibits. The ground floor of the Hall of Achievement will stage a Hall of Metals, which will present a varied range of engineering exhibits organised by the trade associations concerned through the Federation of British Industries to illustrate in comprehensive fashion Great Britain's contribution, by way of research and invention, to the development of efficiency in the use of metals. There will also be a Hall of Democracy, devoted to the history and growth of democracy, which will show that the common democracies of this country and the United States had their origin in England.

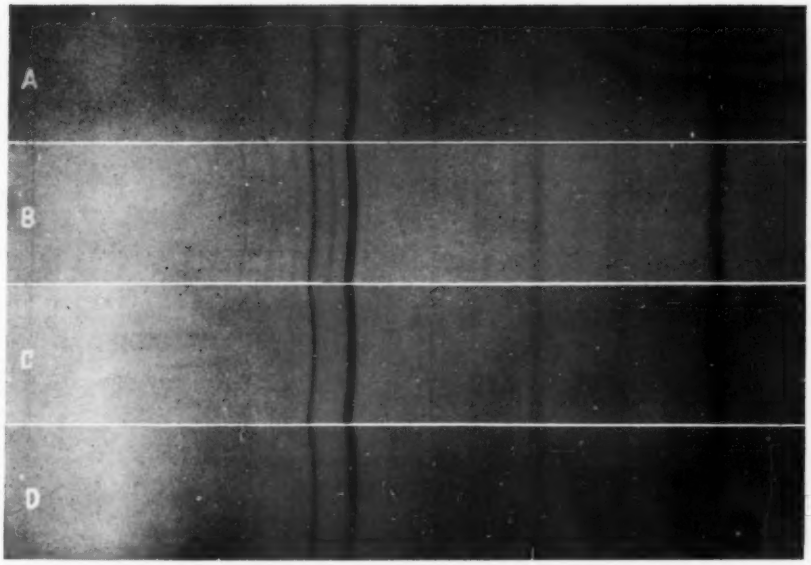
FIRST CLASS PYROMETER SALESMAN with good connection required to sell modern potentiometers and controllers. Good salary, commision and expenses, with prospect executive position London Office for right man. Applications, received in confidence, should state age, M. or S., full details experience, with copies testimonials, and salary desired. Only first class men need apply. Write Box. S.262, Willings, 356, Gray's Inn Road, London, W.C.1.

BRADLEY and FOSTER LTD., Darlaston Blast Furnaces, Darlaston, announce that from October 1st. they will be represented for the sale of their high quality pig irons and Chilled Grit in Lancashire, Yorkshire and in the northern counties by Mr. A. L. Scott, whose address is 19 The Drive, Arden Park, Bredbury, nr. Stockport, telephone number - Woodley 2179.

Lines That Solved A Problem

HERE are the lines—in x-ray diffraction patterns—that led to correction of a faulty manufacturing process, solved a tricky problem.

These four patterns represent four forged bars of a permanent-magnet alloy steel. Coming originally from the same section of the parent ingot, and presumably receiving the same forging and heating treatment, the magnetic properties, nevertheless, were different. Bar A produced a magnet whose high coercivity and remanence were a maximum for the alloy. Bars C and D were of only average quality. In contrast, Bar B was practically worthless as a permanent magnet.



Chemical and spectrographic analysis showed all four to be identical in elementary composition. All four showed identical micro-structures at all magnifications. X-ray diffraction, however, produced three distinctly different patterns, showing definite structural differences.

Pattern A shows the particularly good bar to have the structure of tetragonal martensite, in which all of the alloying constituents are in solid solution. The high residual stresses resulting are indicated by the diffuseness of the diffraction lines. In pattern B are seen several lines in addition to the strong lines in A. Here tetragonal martensite structure is replaced by alpha-iron, the extra lines being from a complex metallic carbide with a cementite structure. This structure indicates that practically all of the alloying constituents have been precipitated, leaving a nearly stress-free alpha-iron bar. The crystallites of the carbide held in the iron matrix are evidently submicroscopic, since they could not be seen under the microscope, and it was for x-ray to reveal the structure indicating magnetic properties in bar B approaching those of soft iron.

Patterns C and D show some lines in addition to those due to alpha-iron or cubic martensite, which were identified as coming from a trace of retained austenite and from a metallic carbide, the latter having a different structure and therefore a composition different from cementite. Thus it is shown that some of the alloying constituents are not in solution in the martensitic lattice and that decomposition of austenite has not been complete. This accounts satisfactorily for the difference in magnetic properties between bars C and D and bar A.

Bars B, C, and D, evidently, had not been heated to a sufficiently high temperature, or had not been held long enough at the proper temperature for complete solution of the carbides to take place before quenching. The difficulty was traced to unequal temperatures in the heat-treating furnace, and was soon eliminated by an adjustment of furnace operating conditions. RESULTS were: an improvement in uniformity of product; decreased losses from rejected material; and elimination of a perennial quarrel between the steel maker and the magnet manufacturer.

You, too, may have problems which can best be solved by x-ray diffraction. One good way to be sure is to consult with our diffraction laboratory staff. Their services are available by writing to Dept. LX.

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MARKET PRICES

ALUMINIUM.

98/99% Purity	£100	0	0

ANTIMONY.

English	£71	0	0
Chinese	53	0	0
Crude	37	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11½
Brazed Tubes	,,	0	1	1½
Rods Drawn	,,	0	0	9½
Wire	,,	0	0	8½
*Extruded Brass Bars	,,	0	0	5¼

COPPER.

Standard Cash	£45	18	9
Electrolytic	51	5	0
Best Selected	51	0	0
Tough	50	10	0
Sheets	82	0	0
Wire Bars	52	5	0
Ingot Bars	52	5	0

Solid Drawn Tubes	lb.	0	1	0¾
Brazed Tubes	,,	0	1	0¾

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	4	9½
‡Ferro Tungsten ° nominal	,,	0	4	8
Ferro Molybdenum °				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2–4% Carbon, scale 12/– per unit	ton	34	15	0
NOMINAL 4–6% Carbon, scale 8/– per unit	,,	24	5	0
NOMINAL 6–8 Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL 8–10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/– per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/– per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/– per unit	,,	12	10	0
70/80% basis 75%, scale 7/– per unit	,,	17	0	0
90/95% basis 90%, scale 10/– per unit	,,	30	0	0
§Silico Manganese 65/75% Mn, basis 65% Mn	,,	18	15	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	0	0
Scotland	—	1	15	0
Durham	—	1	14	6
Furnace Coke—				
Scotland	—	1	10	0
S. Wales	—	1	9	0
Durham	—	1	7	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£67	0	0
*Commercial Ingots		51	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—			
Crown Bars	£13	10	0
N.E. Coast—			
Rivets	12	15	0
Best Bars	15	15	0
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S. Wales	3	10	0
Cleveland	3	10	0
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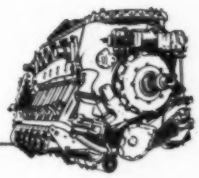

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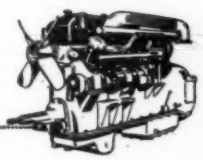

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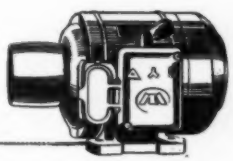

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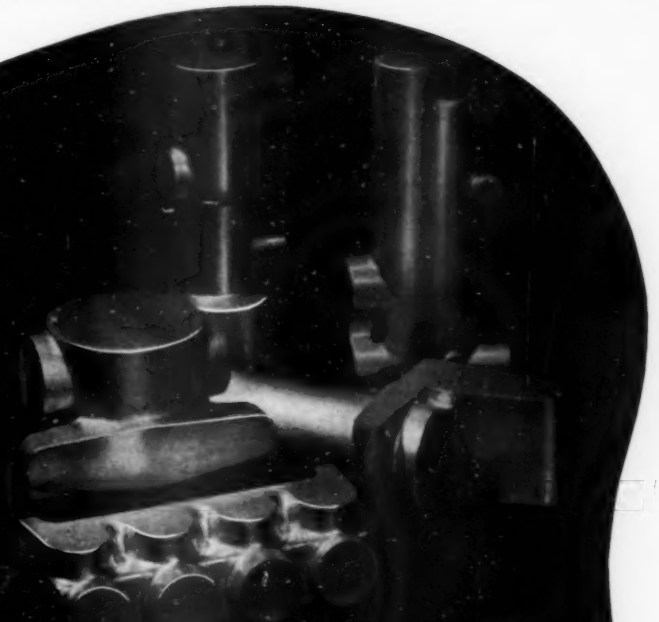

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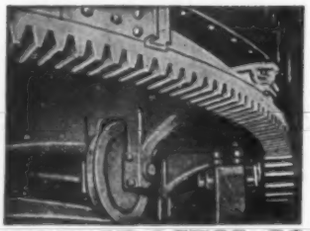

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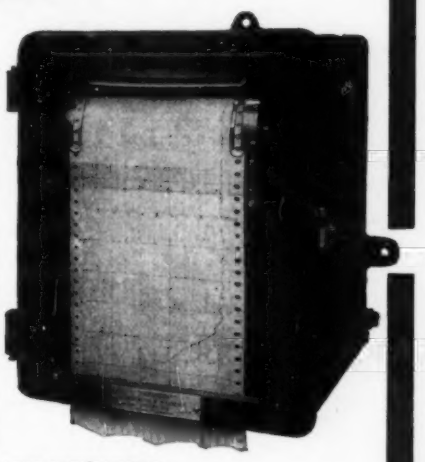

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Victor X-Ray Corporation Ltd., London and Chicago.

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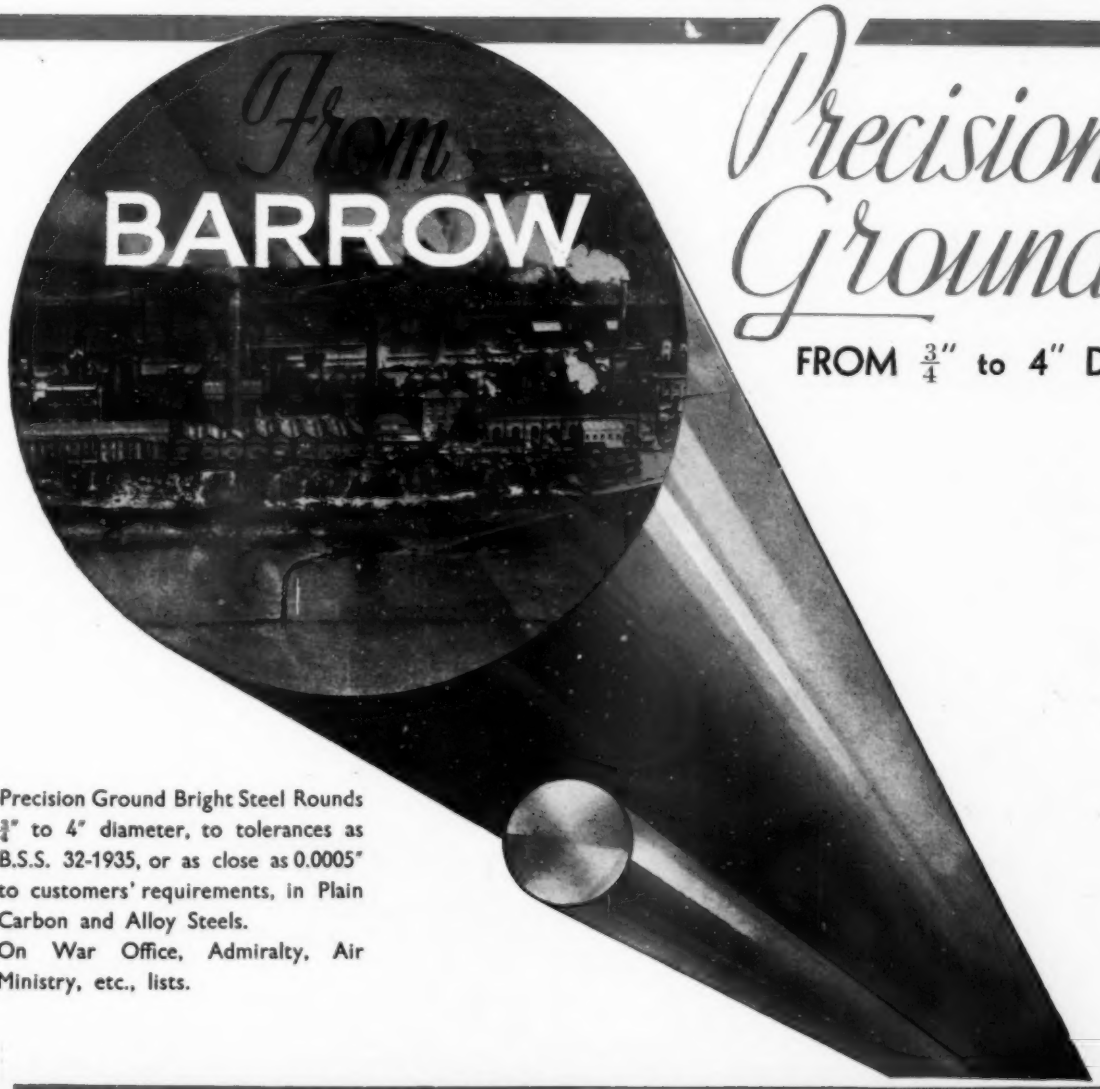

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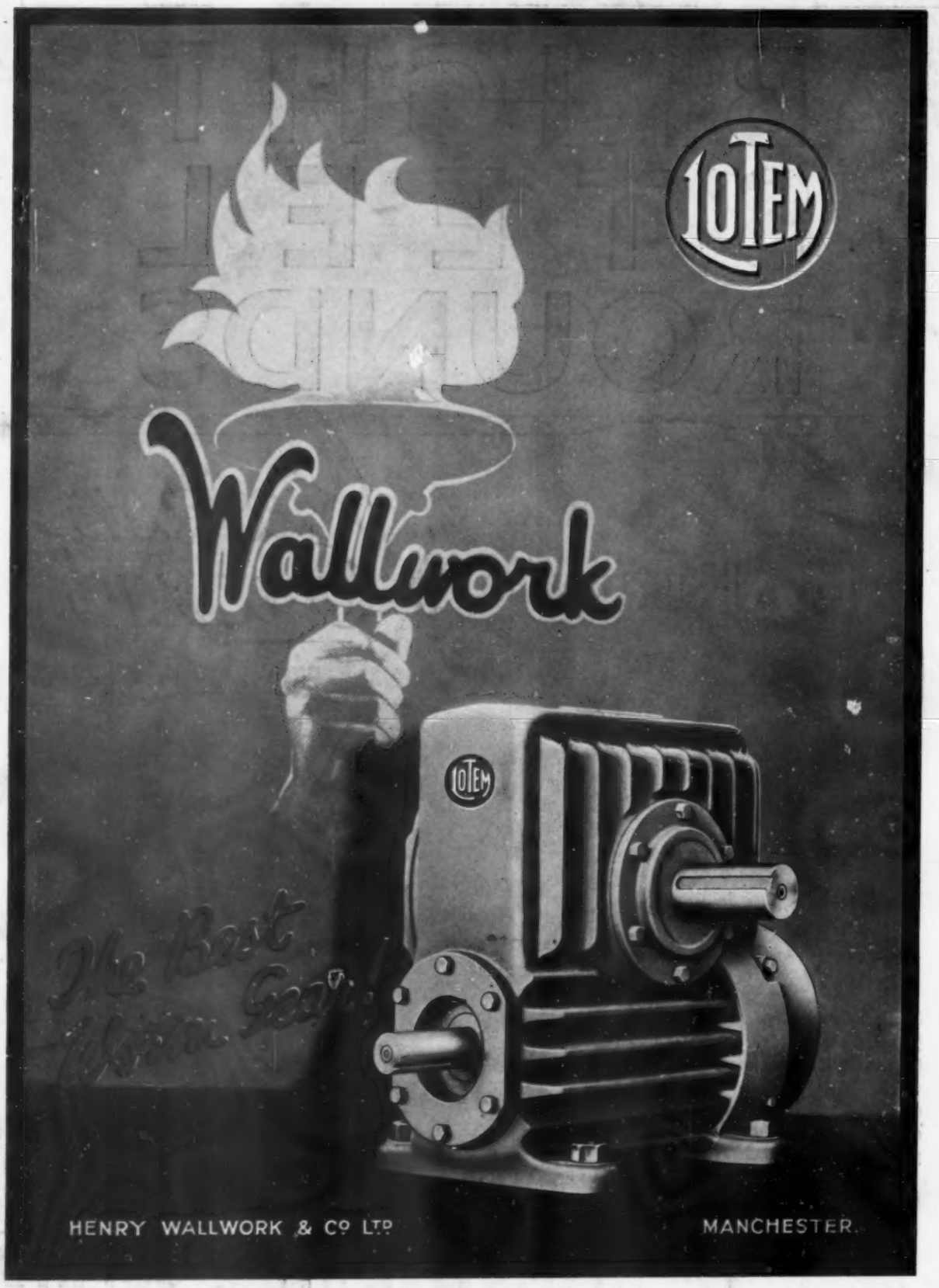
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